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ACHIEVEMENT IN GENERAL CHEMISTRY
AS IT IS RELATED TO
CERTAIN LEARNING ABILITIES

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Achievement in General Chemistry
as It is Related to
Certain Learning Abilities

BY

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TABLE OF CONTENTS

	PAGE
CHAPTER I	
<i>Introduction</i>	11
Background of the problem	
Statement of the problem	
Limitation of the problem	
CHAPTER II	
<i>Research Instruments Used</i>	17
Special tests constructed	
Standardized tests used	
General personnel data	
CHAPTER III	
<i>Description of Subjects</i>	22
Geographical distribution	
Age of subjects	
Sex of subjects	
Nationality	
Occupation of parents	
Year in college	
Intelligence of subjects	
Conclusion	
CHAPTER IV	
<i>Research Techniques Employed</i>	24
The administration of the tests	
The questionnaire	
Statistical techniques	
CHAPTER V	
<i>Results</i>	26
A study of individual differences of students as measured by their performance on the various tests employed	
A study of achievement in general chemistry as the same is related to performance on other tests used.	
A study of achievement in general chemistry as influenced by other factors.	
CHAPTER VI	
<i>Summary of Results, and Conclusion</i>	75
Summary of results	
Conclusions of pedagogical significance	
Problems suggested for further investigation	
<i>Bibliography</i>	83
<i>Appendix</i>	86



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LIST OF TABLES

	PAGE
Table I.—Summary of Results Based on Special Test Number 1.....	27
Table II.—Summary of Results Based on Special Test Number 2.....	31
Table III.—Summary of Results Based on Special Test Number 3.....	33
Table IV.—Summary of Results Based on Special Test Number 4S.....	35
Table V.—Summary of Results Based on Special Test Number 4R.....	37
Table VI.—Summary of Results Based on Special Tests Number 1, 2, and 3.....	38
Table VII.—Summary of Results Based on Complete Battery of Special Tests.....	40
Table VIII.—Summary of Results Based on Special Tests Number 4S and 4R	42
Table IX.—Summary of Results Based on the Whipple Test..	44
Table X.—Summary of Results Based on the Holley Test...	46
Table XI.—Summary of Results Based on the Iowa Chemistry Training Test	48
Table XII.—Summary of Results Based on Teachers' Marks..	51
Table XIII.—Summary of Results Based on the Otis Intelligence Test.....	53
Table XIV.—Summary of Ranges of Tests Used.....	55
Table XV.—Percentage Distribution of Students According to Colleges	56
Table XVI.—Summary of Results Based on Part 4, Iowa Chemistry Training Test (Chemical Arithmetic).....	57
Table XVII.—Correlation of CT1-A Scores with Other Test Scores.....	58
Table XVIII.—Correlation of CT1-B Scores with Other Test Scores	60
Table XIX.—Correlation of Teachers' Marks with Scores on Other Tests.....	61
Table XX.—Correlation of Intelligence Quotients with Other Test Scores	62

	PAGE
Table XXI.—Correlation of Whipple Test Scores with Scores on Other Tests	63
Table XXII.—Correlation of Holley Test Scores with Scores on Other Tests	64
Table XXIII.—Chemistry Training Scores on Basis of Size of High School	68
Table XXIV.—Chemistry Training Test Scores on Basis of Type of School in Which Student Learned to Read.....	70
Table XXV.—Chemistry Training Test Scores on the Basis of the Science Studied in High School.....	71
Table XXVI.—Chemistry Training Test Scores on the Basis of Sex.....	73

LIST OF GRAPHS

	PAGE
Figure 1—Distribution of Scores on Special Test Number 1 . . .	30
Figure 2—Distribution of Scores on Special Test Number 2 . . .	32
Figure 3—Distribution of Scores on Special Tests Number 1, 2, and 3	40
Figure 4—Distribution of Scores on Batteries A and B, Special Tests	42
Figure 5—Distribution of Scores on Special Tests Number 4S and 4R, Both Forms	44
Figure 6—Distribution of Scores on Both Forms of the Iowa Chemistry Training Test	50
Figure 7—Distribution of Intelligence Quotients of the Group .	54

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INTRODUCTION

Many Presidents of Teachers Colleges indulge in the hope that there will be an increasing number of scholar-teachers on their faculties. They also feel that in the school education of such a scholar-teacher, there should be a well balanced diet of professional and subject matter courses. Dr. Bray had this idea in mind in pursuing work for the Doctor's degree. The liberality of the Chemistry and Education groups in the University of Missouri in allowing him to carry out this idea is a mark of a "better day" in University circles. Their action heartens the teaching and administrative groups in Teachers Colleges. It is a pleasure to join Dr. Bray in the publication and distribution of his dissertation.

It is an important and timely piece of work in itself. It is believed that its distribution to other teachers colleges may encourage other teacher-scholars to explore further problems which Dr. Bray suggests.

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ACHIEVEMENT IN GENERAL CHEMISTRY AS IT IS RELATED TO CERTAIN LEARNING ABILITIES

CHAPTER I INTRODUCTION

BACKGROUND OF THE PROBLEM

Systematic efforts to improve instruction are of comparatively recent origin. It has long been assumed that a high percentage of failures is to be expected as a necessary concomitant of college work. Students who could meet minimum entrance requirements have been accepted and have been dealt with collectively without regard to individual differences. These conditions still obtain in the average college and university. The instructor assumes that he has no obligation beyond the presentation of facts and relationships.

For a number of years thoughtful students have observed with concern the high mortality rate in general chemistry classes. Powers found that "there is a high percentage of failures in high school chemistry."¹ He further found that "Superior students find great difficulty with chemistry."² Powers says that "if chemistry is really elective there is a marked tendency for students of poor ability to avoid it."³ In considering the question of variability in the achievement level of students in chemistry, Powers found that "the ability of university students of general chemistry to do the different tasks in these tests given is not appreciably different from that of students who have studied the subject in the better high schools."⁴

This conclusion is also reached by Cornog and Stoddard. These investigators found a real, though not impressive, difference in favor of those who were completing first year college chemistry over those who had studied chemistry in high school and who took the same test at the first of the year.⁵

¹Powers, S. R., *A Diagnostic Study of the Subject Matter of High School Chemistry*, Teachers College, Columbia University, Contributions to Education No. 149, (1924), p. 2.

²*Ibid.*, p. 2.

³*Ibid.*, p. 31.

⁴*Ibid.*, p. 55.

⁵Cornog, Jacob and Stoddard, Geo. D. Predicting Future Student Performance from Their Past Records, *Journal of Chemical Education*, Vol. VI, (1929), p. 97.

Powers also found that "the ordinary intelligence test gives a poor indication of ability to achieve in general chemistry."⁶ It is reasonable to assume that the same conditions found by Powers for high school chemistry might also be found in the colleges.

Maxwell has observed that, of the colleges in the North Central Association of Colleges and Secondary Schools and of the Southern Association, "state universities and state colleges failed 33.3 per cent of the students while teacher training institutions failed 17.2 per cent, junior colleges failed 21.3 per cent, and private colleges and universities failed 25.9 per cent. The respective percentages of semester hours failed were 12.7 per cent, 5.5 per cent, 20.9 per cent, and 24.2 per cent. Findings in this study verify findings of a study made in 1924-25."⁷ Maxwell found that college freshmen in the North Central Association failed 12.2 per cent of the science credit for which they were enrolled, while college freshmen in the Southern Association failed 19.2 per cent of the science credit for which they were enrolled.

Osborn has observed that 14.75 per cent of a group of students preparing for chemical engineering, pharmacy, agriculture, and mining failed in general chemistry.⁸ Lemon observed that, during the period 1914 to 1918 inclusive, 14 per cent of his physics students failed. Possibly the same factors operate in the field of chemistry as in the field of physics.⁹

Silverman reports between 20 and 30 per cent of failures in general chemistry reduced to 10 per cent or less by intensive instruction.¹⁰ Moss, Loman, and Hunt found that, in twenty-eight land grant colleges in the United States, the median chemistry score on their test was 14 points lower for colleges in the Middle Western States than for colleges in the North Atlantic or Far Western States, and lower than in any other section of the country.¹¹ Currier found, among college students who had not stud-

⁶Powers, S. R., Op. cit., p. 81.

⁷Maxwell, C. R., A Report on College Freshmen for the First Semester 1928-29, *North Central Association Quarterly*, Vol. IV, (1930), pp. 484-600.

⁸Osborn, R. A., First Year College Chemistry Students from the School of Agriculture, *Journal of Chemical Education*, Vol. VI, (1929), p. 2189.

⁹Lemon, H. B., Forecasting Failures in College Classes, *School Review*, Vol. XXX, (May 1922), p. 382.

¹⁰Silverman, Alexander, Intensive Training in Chemistry, *Journal of Chemical Education*, Vol. V, (1928), p. 317.

¹¹Moss, F. A., Loman, William, and Hunt, Thelma, Impersonal Measurements of Teaching, *Educational Record*, Vol. X, (January 1929) pp. 40-45.

ied high school chemistry, 39 per cent of failures and, among those who had studied high school chemistry, 13 per cent of failures.¹²

It would seem that a period has been reached in our educational development when it can no longer be assumed that the very large number of those who do not succeed in general chemistry fail solely because of the inherent difficulty of the subject or because of the inferior mentality of the students. Probably these reasons have too long been taken for granted by most chemistry teachers. It seems certain that improvement in chemistry teaching must be based largely upon careful consideration of the individual differences of students as to the fundamental abilities that operate in the study of the subject.

There are many abilities that should be considered in making a complete study of this question. There is probably no doubt that reading ability is one of the serious problems that condition success in the study of general chemistry. Skinner found that "it is possible that scores on reading ability based on several types of college subjects would be a much better index of achievement than any test score or combination of tests now in use."¹³ Arnold found that there is urgent need for careful study of the necessary background for college work. He states that the exact nature and extent of student difficulties should be determined by diagnostic tests. He further states that the college should develop remedial self-instruction for all handicapped students, and that such a plan will certainly reduce failures and raise the general standard of scholarship.¹⁴ Arnold found that these difficulties generally involve so-called tool subjects.

One of the earliest investigators to describe individual differences in reading ability of college and university students is Quantz, who published his observations in 1897. He found that speed in reading is an indication of superior work and better retention and that lip movements constitute a handicap to effective reading.¹⁵ Variability in the character of eye movements in the

¹²Currier, A. J., The Sectioning Problem in General Chemistry, *Journal of Chemical Education*, Vol. VIII, (1931), p. 330.

¹³Skinner, H. Clay, Relationship between Reading Ability and Class Marks in College Subjects, *Journal of Educational Research*, Vol. XVII, (February 1928), p. 137.

¹⁴Arnold, H. J., Disabilities of College Students in Certain Tool Subjects, and the Relation of Such Disabilities to College Standing, *Phi Delta Kappan*, Vol. XI, (April 1929), p. 169.

¹⁵Quantz, J. O., Psychology of Reading, *Psychological Review, Series of Monograph Supplements*, Vol. II, No. 1, (December 1897), pp. 49-50.

reading of university students is described by Judd and Buswell¹⁶ and by Gray.¹⁷ They found that the period of fixation varies with the individual and with the type of material read as well as with the purpose in reading.

Webb found very significant correlation between the reading ability of college students and their performance on certain mental tests.¹⁸ Good found that extensive reading is superior to intensive reading in range and accuracy of information, in ability to see relations, and in problem solving ability.¹⁹ It was found by Book that a group of students in Indiana University who failed in an orientation course were poor readers.²⁰ He comments on the marked differences in reading ability as measured by the Whipple Reading Test. Although Book mentions no correlations in his study, he points out that there is a high correlation between reading ability and success in academic subjects.

Many other investigations of differences in reading ability of students of secondary and elementary school grades have been made. Indications are all to the same effect. One of the most interesting of all of these Studies is that made by Irion dealing with ninth grade pupils. He shows clearly the effects of individual differences in the ability of pupils to comprehend English literature.²¹ Anderson also found extreme individual differences in reading ability of university students in educational psychology. He found that ability to read material in educational psychology is a fair indication of scholarship in the course.²²

While these studies do not deal specifically with the field of college chemistry, it is reasonable to suppose that the problem of

¹⁶Judd, Chas. H. and Buswell, G. T., *Silent Reading, A Study of Various Types*, *Supplementary Educational Monographs No. 23*, University of Chicago, (1922).

¹⁷Gray, C. T., *Types of Reading as Exhibited Through Tests and Laboratory Experiments*, *Supplementary Educational Monographs No. 5, I*, University of Chicago, (1917).

¹⁸Webb, L. M., *Ability in Mental Tests in Relation to Reading Ability*, *School and Society*, Vol. XI, (May 8, 1920), pp. 567-570.

¹⁹Good, C. V., *An Experimental Study of the Merits of Extensive and Intensive Reading in Social Sciences*, *School Review*, Vol. XXXIII, (1925), pp. 755-770.

²⁰Book, William F., *How Well College Students Read*, *School and Society*, Vol. XXVI, (August 20, 1927), p. 242.

²¹Irion, Theo. W. H., *Comprehension Difficulties in the Study of Literature*, Teachers College, Columbia University, *Contributions to Education No. 189*, (1925), p. 71.

²²Anderson, E. M., *Individual Differences in the Reading Ability of College Students*, *University of Missouri Bulletin, No. 25*, Education Series, (1928), p. 53.

individual differences in reading ability in the field of chemistry might be just as pronounced, and in every respect as significant as in the fields covered by these investigators.

STATEMENT OF THE PROBLEM

It is the object of this investigation to throw some light upon the following questions:

1. To what extent do college students entering upon a study of general chemistry know how to read chemical literature?
2. Do college students of general chemistry lack general reading ability? If so, to what extent?
3. To what extent is the ability to read chemical literature related to achievement in general chemistry?
4. Do college students in general chemistry find themselves handicapped by a lack of mastery of general vocabulary? If so, to what extent?
5. What relationship exists between general reading ability and achievement in general chemistry?
6. To what extent is knowledge of chemical vocabulary related to achievement in general chemistry?
7. What relationship exists between ability to read for directions and achievement in general chemistry?
8. What relationship exists between ability to solve a chemical laboratory problem and achievement in general chemistry?
9. What relationship exists between intelligence and ability to achieve in general chemistry?
10. To what extent do individual students tend to differ in reading ability, in intelligence, and in achievement in general chemistry?

MINOR QUESTIONS TO BE CONSIDERED

1. Does the size of the high school from which the student graduated bear any relationship to his success in the study of general chemistry in college?
2. Is there any relationship between the type of school in which the student learned to read and his success in college general chemistry?
3. Is there a significant difference in the success of students of general chemistry on the basis of sex?

4. Do the sciences studied in high school tend to influence success in the study of general chemistry in college?

5. How do teachers' marks compare with other measures of success in general chemistry?

LIMITATION OF THE PROBLEM

It is recognized that there are other important factors which might influence success in the study of general chemistry, but no attempt is made in this study to evaluate their relative importance. This study will be limited to a consideration of the phases of the problem covered in the above questions.

CHAPTER II

RESEARCH INSTRUMENTS USED

SPECIAL TESTS CONSTRUCTED

Since it appears that, among other abilities which function in the study of chemistry, the ability to read expositive chemical literature, a knowledge of the technical vocabulary, the ability to read for directions in the study of chemistry, and the ability to think one's way into the solution of a chemical laboratory problem are of considerable importance, it was found necessary to measure these traits. The literature was studied thoroughly for tests which might be used for this purpose, but none was found.¹ It then became necessary to construct such tests. Accordingly, five tests were prepared, each test being constructed in two substantially equivalent forms, as follows: The Expositive Reading Test, Number 1; Chemistry Vocabulary Test, Number 2; the Reading for Directions Test, Number 3; the Test of Ability to Select the Steps Necessary to the Solution of a Chemical Laboratory Problem, Number 4S; and the Test of Ability to Rank the Steps that are Necessary in the Solving of a Chemical Laboratory Problem, Number 4R.

THE EXPOSITIVE READING TEST, NUMBER 1

In the construction of this test, a careful analysis of a number of the most widely used textbooks of general chemistry for colleges was made in order to secure reading selections which were typical. Such typical selections having been found, they were paired as carefully as possible into two approximately equivalent groups. These reading selections were thus prepared and were followed by a number of multiple choice responses to questions as to important fact items contained in the reading selections. The first test constructed consisted of six short reading selections, each containing a single brief paragraph with 30 fact items to each form of the test.

When this test was administered to a typical group of college students of general chemistry, it was found that the coefficient of reliability obtained was too low (0.77). It seemed probable

¹A chemistry reading test by L. C. Pressey was described in the *Journal of Higher Education*, Vol. II, (1931), p. 30, as being in use in Ohio State University.

that this low reliability might be due to the use of reading selections that were too brief to be typical. In order to test this point, the two forms were thrown together to make one long test. The evens were then correlated against the odds. This gave an index of reliability of 0.90. This seemed to indicate fairly definitely that the reading selections were too short to yield satisfactory results. For this reason the test was revised, and made to consist of three reading selections to each form of the test, the selections being chosen as indicated above for the first arrangement of the test.

Each reading selection was made to consist of about a printed page of reading material, followed by multiple choice responses to a number of promiscuously arranged fact items taken from the reading selections. The student was instructed to mark the correct response in each case. This revised test was then administered to a typical group of college students of general chemistry. A correlation of form against form gave an index of reliability of 0.85. In each case the two forms of the test were administered within one week in order to avoid the introduction of error as a result of improvement incident to the study of the subject in college. There was, in all of the reading selections, a total of 40 fact items to each form of the test to which the student was asked to react.

In the construction of each of these special tests, the suggestion given by Irion, to the effect that the error caused by guessing be minimized by making one of the incorrect responses as attractive as possible, was kept in mind.²

THE CHEMISTRY VOCABULARY TEST, NUMBER 2

A list of approximately 200 technical words used in general chemistry was adapted from the chemistry word list prepared by Pressey.³ The words selected were from those considered most important for high school chemistry by Pressey, the selection being on the basis of the author's experience and judgment as to which constitute really key words in the study of general chemistry in college. From this list of words 30 words were elected for each form of the test.

²Irion, Theo. W. H., *Op. cit.*, p. 13.

³Pressey, L. C., *The Determination of Technical Vocabulary of School Subjects*, *School and Society*, Vol. XX, (July 19, 1924), p. 91.

In order to study the relative difficulty of the words selected, they were compared with the Powers word list.⁴ Thirty per cent of the words in Form A were found to occur 30 times or oftener in the textbooks analyzed by Powers, while 60 per cent of the words were found to occur in two or more sciences, including chemistry, assuming the 12 words in this list not listed by Powers to be strictly chemical terms. Forty per cent of the words occur in three or more sciences. Since 55 per cent of this list of words were listed by Powers as important for high school chemistry, it seems certain that the list is a representative one for college chemistry.

A study of the words in Form B list reveals similar facts. Eighty per cent of the words in the list are listed by Powers, 60 per cent of the words occur 20 times or oftener, while 47 per cent occur in three or more sciences, including chemistry. It would appear, therefore, that the Form B list of words is also typical and suitable for the present study.

Following each word in the test were given five multiple choice responses, one of which was correct. The student was asked to mark the correct response in order to indicate the meaning of the word as used in chemical literature. The two forms of this test were administered within one week to a typical group of college general chemistry students. A correlation of form against form gave an index of reliability of 0.87. The final form of the test was enlarged from 30 to 38 words to each form of the test. This increased the index of reliability of the test to 0.89 when calculated by Brown's formula.⁵

THE READING FOR DIRECTIONS TEST, NUMBER 3

In the selection of the material to make up this test, a careful study was made of a number of the most commonly used laboratory manuals in general chemistry, and directions for experiments were selected which were found to be typical. These selections were adapted to the present purposes and arranged in two groups of approximately equal difficulty. In this test, as in the Expository Reading Test, the student was asked to select the main theme of each selection read. The student was also asked to indicate

⁴Powers, S. R., *Technical Terminology of Textbooks in Secondary Science, Teachers Journal and Abstract*, Vol. II, (November 1927), pp. 625-628.

⁵Brown, William, *The Essentials of Mental Measurement*, Cambridge University Press, London, (1911), p. 102.

the successive steps to be carried out as given in the reading selections. The multiple choice form was used. Each form was made to consist of six reading selections with a total possible score of 42. When the test was administered to a typical college chemistry group and the scores correlated, form against form, an index of reliability of 0.95 was obtained.

THE TEST OF ABILITY TO SOLVE A CHEMICAL LABORATORY PROBLEM

It seems certain that ability to think one's way to a solution of a chemical laboratory problem might contribute to success in the study of general chemistry. A careful consideration of this ability indicated that there are at least two distinct abilities which function in the solving of such problems. One is the ability to select the steps that would have to be carried out in the solving of the problem, and the other is the ability to rank those steps in the order in which they would be carried out in the laboratory. The laboratory problem which these tests contemplate is not the traditional laboratory exercise in which the student merely follows printed directions, but a learning exercise in which a chemical fact is stated, along with a problem based upon that fact which one might be called upon to work out in the laboratory.

In the selection of typical problems, a study was made of a number of commonly used laboratory manuals in general chemistry, and from the exercises given in them a number of laboratory problems were formulated. The problems were arranged as nearly as possible according to their difficulty in two substantially equivalent lists. Each form of the test was made up of six such problems. Before each problem was stated, the underlying chemical facts were simply set forth. Then the problem was stated as clearly as possible. The student was given specific directions as to how to proceed. There were a number of possible steps given below the statement of the problem, some of them being irrelevant and some being necessary to the solution of the problem.

In order to avoid confusion in ranking, the problems were so chosen that the steps could be arranged in only one correct order. In the single exception to this rule, allowance in scoring the test was made to permit either of two possible rankings to be used. The student was asked to indicate the steps that would have to be carried out in solving the problem by encircling the number

which stood before each of the steps selected. After the correct steps had been thus marked, the student was asked to indicate, in blank spaces to the right of the statements, the order in which these steps should be carried out.

This resolved itself into two separate tests; namely, the Test of Ability to Select the Steps Necessary to the Solving of a Chemical Laboratory Problem, Number 4S; and the Test of Ability to Rank the Steps that are Necessary to the Solution of a Chemical Laboratory Problem, Number 4R. These tests were administered to a typical group of college students of general chemistry, and the index of reliability was found by correlating form against form. It was found that in Special Test, Number 4S, it was necessary to use the right minus wrong formula to correct for guessing. These two tests were each found to have an index of reliability of 0.87.

STANDARDIZED TESTS USED

In order to measure the general reading ability of the students under study the Whipple High School and College Reading Test, Form B, was used. Since this test is constructed of reading material of a general nature entirely outside the field of chemistry it was thought that it might very well be used as a criterion, as well as a measure of the unanalyzed general reading ability of the group.

After the study was well under way, it seemed advisable to use the Holley Sentence Vocabulary Scales, Series 3B, as an additional criterion, as well as for measuring the students' command of general vocabulary.

In order to measure the intelligence of the subjects, the Otis Self-Administering Test of Mental Ability, Higher Examination, Form C was used.

The Iowa Chemistry Training Test was selected for use as an instrument for measuring achievement in the field of chemistry, one form of the test being used at the beginning of the term, and the other at the end of the term.

GENERAL PERSONNEL DATA

In order to obtain the data concerning each student, a questionnaire was formulated which called for a simple statement of the important facts desired regarding each student. The questionnaire was constructed and administered in such manner as to secure the normal reaction of each subject and to obtain a maximum of reliability in data.

CHAPTER III

DESCRIPTION OF SUBJECTS

In order that the results of this study might be valid, a fairly large, unselected group of college students was sought that would be as representative and typical as possible. In order to ascertain whether the group selected for this study met this requirement, data concerning geographical distribution, age, sex, nationality, occupation of parents, and year in college were obtained by means of a questionnaire. These characteristics are now discussed in order to establish the typical character of the subjects used in this study.

GEOGRAPHICAL DISTRIBUTION

In order to avoid local influences, four state teachers colleges in Missouri were selected in widely separated sections of the state, and one standard arts college. The colleges co-operating in this study were the Southeast Missouri State Teachers College, Cape Girardeau; the Southwest Missouri State Teachers College, Springfield; the Central Missouri State Teachers College, Warrensburg; the Northeast Missouri State Teachers College, Kirksville; and Culver-Stockton College, Canton, Missouri. Approximately 325 students were enrolled in the beginning general chemistry classes in these five colleges. These constitute the subjects used in this study.

AGE OF SUBJECTS

The age of the students in this group averaged 19.25 years. The range in ages was from 15 to 33 years. About 87.6 per cent of the group were between 17 and 22 years of age, inclusive. The group studied, therefore, was of the age of typical college students.

SEX OF SUBJECTS

The group studied were found to be 61.2 per cent men, and 38.8 per cent women. Although the men are largely in the majority, the women furnish a sufficiently large number of cases to be significant in the present study, and to insure the representative character of this group as regards sex.

NATIONALITY

The nationality of the subjects is almost exclusively American, of English, Irish, Scotch, Welch, German, and French ancestry. The subjects are, therefore, typical of the stock found in the middle western part of the United States.

OCCUPATION OF PARENTS

Of the group studied 43.9 per cent are sons or daughters of farmers; 16.02 per cent are children of laboring men; 14.63 per cent are children of business men; 12.89 per cent are children of men engaged in clerical work or salesmanship; 10.45 per cent are children of professional men; and 2.1 per cent are children of men reported as having no occupation or as being retired. This gives a fair sampling of subjects from the different occupations found in a state which is largely agricultural. In this respect, also, the subjects may be considered as representative and typical.

YEAR IN COLLEGE

It was found that 54 per cent of the group were freshmen, 27 per cent were sophomores, while 19 per cent were upper classmen. It is to be expected that a very large majority of this group would be enrolled in the junior college, since general chemistry is nearly always a junior college course. In this regard, also, this group may be considered typical.

INTELLIGENCE OF SUBJECTS

The intelligence of the subjects was studied by means of the Otis Self-Administering Test of Mental Ability, Higher Examination, Form C. The distribution of intelligence quotients range from 79 to 131, with a mean I. Q. of 105.67, and a standard deviation of 10.33. The mean of this group is approximately 5 points lower than the norm for this test. It is believed that, in intelligence the present group approximates the normal group closely enough to be classed as typical for the purposes of this study.

CONCLUSION

From the facts set forth in this chapter, it appears that the group is typical of general chemistry students in colleges, and in all respects satisfactory for the present study.

CHAPTER IV

RESEARCH TECHNIQUES EMPLOYED

This study was begun at the first of the fall quarter of the school year of 1929-1930. It was desired to measure the abilities which the five Special Tests constructed for this study are designed to measure, not only at the beginning of the term, but also at the end of the term. In addition to this it was thought desirable to measure achievement in chemistry, both at the beginning and at the end of the term, and to measure general reading ability and intelligence at the beginning of the term. Near the end of the term it was found necessary to measure the command of general vocabulary.

The techniques employed in this study were determined largely by the nature of the problem. Since the problem is exploratory in character, determining abilities that might function in the study of chemistry, the test and measurement techniques are necessarily the ones largely employed.

THE ADMINISTRATION OF THE TESTS

It is recognized that the validity of a test depends to a large extent upon its administration. One must make sure that as nearly normal classroom conditions as possible are maintained during the test. The directions for administering each of the Special Tests were carefully designed to meet this need. In addition to this, each instructor cooperating in the study was carefully instructed so that his fullest cooperation might be had in the proper administering of the tests.

Special effort was made to see that the students approached the test in a normal frame of mind. The tests were given as a regular part of the classroom procedure, under the regular instructor. All announcements and remarks were omitted before beginning the test.

In the administration of all of the standardized tests, the directions for administering the tests as published were followed. In all tests having a time limit, the exact timing was kept to the nearest second. No directions other than those printed in the tests were given. The tests were given during the regular class

period, by the regular instructors, and under conditions as nearly normal as possible.

The tests were given in the following order:

Special Test Number 1A, The Expositive Reading Test

Special Test Number 2A, the Chemistry Vocabulary Test

Special Test Number 3A, the Reading for Directions Test

Special Tests Number 4AS and 4AR, Test of Ability to Solve a
Chemical Laboratory Problem

Form A of the Iowa Chemistry Training Test

The Otis Self-Administering Test of Mental Ability

The Whipple High School and College Reading Test

Special Test Number 1B, the Expositive Reading Test

Special Test Number 2B, the Chemistry Vocabulary Test

Special Test Number 3B, the Reading for Directions Test

Special Tests Number 4 BS and 4 BR, Test of Ability to Solve a
Chemical Laboratory Problem

Form B of the Iowa Chemistry Training Test

The Holley Sentence Vocabulary Test

THE QUESTIONNAIRE

The questionnaire used was a simple form which the students were asked to fill out at the beginning of a class period. It was administered under the supervision of the regular instructor and under conditions that would obtain from the student the most nearly normal reactions. The information called for included data concerning the personal history of the student and was of such nature that it would lend itself readily to statistical treatment.

STATISTICAL TECHNIQUES

Since the problem involved in this study deals largely with the measurement techniques, it follows, necessarily, that the statistical techniques commonly employed in such studies be used. All calculations were made with the greatest care, using a calculating machine. All copying and transferring of data were checked with great care. Results were frequently rechecked or recalculated where any irregularities seemed to indicate a possible error.

CHAPTER V

RESULTS

INTRODUCTION

In Chapter I the problem under investigation is discussed with such background as was found necessary for a clear understanding of the question. In Chapter II the research instruments used in this study are discussed, including a somewhat elaborate statement of how the Special Tests were constructed for this study. In Chapter III a description of the subjects used is given. It is recognized that the value of such a study as this depends largely upon the typical character of the group studied. It has been shown that the subjects used in this study may properly be considered to be typical and representative. Chapter IV deals with the research techniques employed.

In the present chapter the results obtained from the several tests are given and discussed. The results are summarized and the conclusions stated in Chapter VI.

The results are considered under the following general headings:

1. A Study of Individual Differences of Students as Measured by Their Performance on the Various Tests Employed.
2. A Study of Achievement in General Chemistry as the Same is Related to Performance on Other Tests Used.
3. A Study of Achievement in General Chemistry as influenced by Other Factors.

1. A STUDY OF INDIVIDUAL DIFFERENCES OF STUDENTS AS
MEASURED BY THEIR PERFORMANCE ON THE VARIOUS
TESTS EMPLOYED

Since this study is concerned with achievement in general chemistry and with the ability to learn, it is necessary to make careful observation with regard to central tendencies and measures of dispersion by means of which the performance of the group might be judged. Tables are presented showing the distribution of scores with the mean and the median as measures of central tendency, and the quartile deviation, or Q , the standard deviation or sigma, $S. D.$, and coefficient of variability, V , as measures of dispersion or variability. In addition to these the 25 percentile point, Q_1 , the 75 percentile point, Q_3 , and the standard error of the

average are shown. The coefficient of variability is given because it affords a convenient method of indicating dispersion, since it represents the percentage that the standard deviation is of the mean of the distribution.

The various tests employed are now described in order, and the distribution tables are shown for each, as well as for certain combinations of tests arranged as batteries.

SPECIAL TEST NUMBER 1, THE EXPOSITIV READING TEST

As has already been indicated, achievement in the study of chemistry must be related, to some extent at least, to ability to read the type of literature found in general chemistry textbooks. The question to be considered now is how well typical college students read that kind of literature. For the purposes of this test, reading may be considered a series of reactions to fact items stated in the selections read.

Anderson found that "the best students in a course in educational psychology are reading to about 50 per cent capacity for the most part, while the poorest students are not working to capacity but are comprehending only about 20 to 30 per cent of the more difficult material and from 50 to 60 per cent of the easier material."¹

He also found that many college students cannot read sufficiently well the ordinary assignments in educational psychology, and that there are very great individual differences in the ability of college students to read that type of literature.

The results obtained from Special Test Number 1, the Expositive Reading Test, are given in Table I.

TABLE I
SUMMARY OF RESULTS BASED ON SPECIAL TEST NUMBER 1

Score	Frequencies, Form A	Frequencies, Form B
39-40	1	0
37-38	1	1
35-36	2	2
33-34	14	1
31-32	9	5
29-30	13	9
27-28	20	11

¹Anderson, E. M., *Op. cit.*, p. 53.

TABLE I—*Continued*

Score	Frequencies, Form A	Frequencies, Form B
25-26	28	13
23-24	38	24
21-22	40	21
19-20	37	28
17-18	35	32
15-16	34	38
13-14	29	33
11-12	9	27
9-10	8	32
7- 8	3	22
5- 6	0	6
3- 4	2	1
1- 2	1	1
Number	323	307
Range	33	33
Mean	22.03	16.85
Median	21.18	16.76
S. D.	6.46	6.75
Q ₁	16.69	12.07
Q ₃	25.45	21.98
Q	4.38	4.95
S. E. of Av.	.36	.39
V	29.32	40.05

A study of Table I shows that, on Form A of this test, given at the beginning of the term, the mean score is 22.05 out of a possible 40. This indicates that the average student was able to read expositive chemical literature with an efficiency of about 55 per cent. The student at the 25 percentile point read with an efficiency of about 41.7 per cent, while the one at the 75 percentile point read with an efficiency about 1.5 times as great. The poorest student in the group scored only 5 per cent of the possible score, while the best scored 97.5 per cent of the possible score. As indicated by this test, the best student reads with an efficiency of about 19.5 times that of the poorest. The coefficient of variability is 29.32, indicating a wide range of individual differences of students' ability to read expositive chemical literature.

In both forms of this test the student was also asked to select the main theme of each reading selection. About 34 per cent of the group were unable to select a single one of the main themes, 43 per cent were able to select only one; 19.9 per cent were able

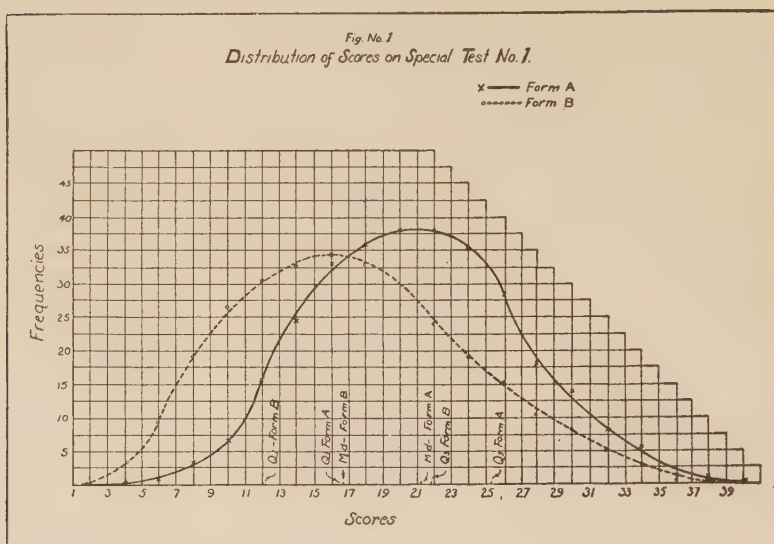
to select two, while only 2.8 per cent were able to select all three of the main themes. This would seem to indicate not only that students have difficulty in reading this type of literature so as to be able to react to the fact items given, but also that they have great difficulty in stating the main thought or theme of the selections read.

A study of the results obtained from Form B of this test, given at the end of the term, shows a mean score of 16.85. This is appreciably lower than the mean of Form A of this test, although these two forms showed a high correlation on the pre-tests and with practically no difference between the means. No reason is given for this apparent decrease in the ability of the students to read expository chemical literature during the first quarter of their study of college chemistry. There is certainty of a real difference greater than zero in favor of the average of Form A over the average of Form B of this test.

The range of scores on the two forms of this test is the same (33), while the coefficient of variability in Form B is about 1.36 times that in Form A. The mean score on Form B is about 42 per cent of the possible score. The best student was able to read, as indicated by the results on Form B, with an efficiency of about 18.4 times that of the poorest. There is good reason to believe that reading expository literature is not itself a simple function. On that part of the test which measures the ability to select the main theme of the selections read there was a distinct improvement at the end of one quarter's study of chemistry. On that part of the test which measures the ability to react to the individual fact items there appeared to be a significant decrease in the mean score. Since the score on the former ability was such a small part of the total score, as the test was constructed, the total results indicate an apparent loss.

The results shown in Table I appear to indicate that an assignment of proper length for the better students will involve serious difficulties for a large part of the group of students. Such an assignment would probably be more than twice as difficult for the average student in the lower fourth of the group than it would for the average in the upper fourth. This would indicate that an assignment that would require an hour and a half for the latter student would require more than three hours for the former student to acquire a much less perfect mastery of the selections read.

The distribution of scores on the two forms of this test are shown graphically in Figure 1.



THE CHEMISTRY VOCABULARY TEST, SPECIAL TEST NUMBER 2

Reading is a more or less complicated process involving a number of abilities. One of the important functions that should be considered in measuring the ability of a student to read chemical literature is a knowledge of chemical vocabulary. Special Test Number 2 is designed to measure this trait.

Irion found as a result of his study of ninth grade pupils that "word knowledge seems to stand out as a very significant item in reading comprehension."² He found that, of 170 pupils, the average word knowledge was 57.5 per cent of the "pivotal" words in the literature selections read. It seems reasonable to assume that a similar condition might obtain in the case of college students and their relation to chemical literature.

Terman found that there is a high correlation between word knowledge and intelligence,³ while Schwesinger found essentially the same thing as between native ability and social-ethical vocab-

²Irion, Theo. W. H., *Op. cit.*, p. 72.

³Terman, Lewis M., *The Measurement of Intelligence*, Houghton Mifflin and Company, p. 230, (1916).

ulary.⁴ Although some of these studies relate specifically to general vocabulary, it is reasonable to suppose that probably similar facts might exist in regard to technical vocabulary.

Table II gives a summary of the results obtained from the Chemistry Vocabulary Test, Special Test Number 2.

TABLE II
SUMMARY OF RESULTS BASED ON SPECIAL TEST NUMBER 2

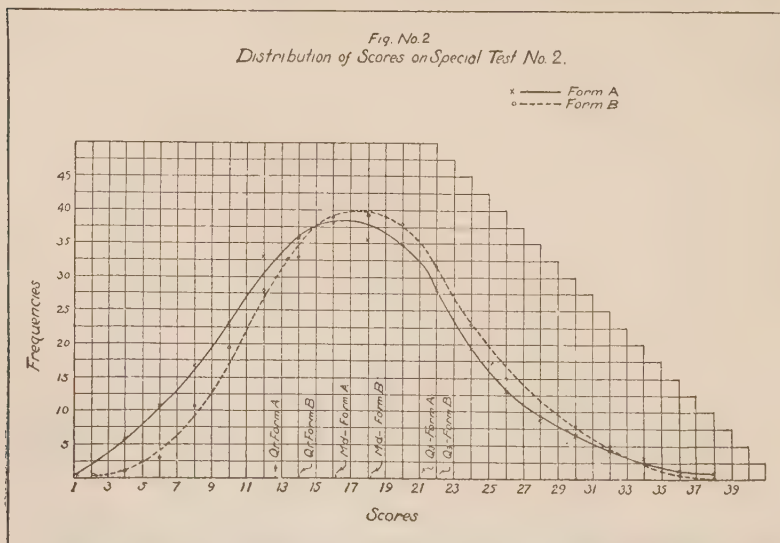
Score	Frequencies, Form A	Frequencies, Form B
37-38	0	0
35-36	1	1
33-34	4	3
31-32	5	5
29-30	7	7
27-28	9	13
25-26	11	9
23-24	20	24
21-22	26	35
19-20	39	38
17-18	41	41
15-16	29	39
13-14	44	34
11-12	35	27
9-10	20	24
7- 8	14	6
5- 6	17	3
3- 4	1	0
1- 2	0	0
Number	328	309
Range	28	30
Mean	16.85	17.87
Median	16.28	18.05
S. D.	6.40	5.79
Q ₁	12.72	14.01
Q ₃	21.15	22.13
Q	4.22	4.06
S. E. of Av.	.35	.33
V	37.98	32.40

A study of Table II shows that on Form A of this test, given at the beginning of the term before the students had studied any chemistry in college, the average of the group knew 44.5 per cent

⁴Schwesinger, Gladys C., *The Social Ethical Significance of Vocabulary*, Teachers College, Columbia University Contributions to Education No. 211, (1926), p. 70.

of the technical words in the test. The student at the 25 percentile point knew about 33.5 per cent of the technical words met, while the one at the 75 percentile point would probably know 1.65 times as many words. The poorest student in the group had a technical word knowledge of about 13.3 per cent of the words in the test, while the best student had a technical vocabulary about 6.6 times as great.

When it is considered that, in general, each such technical word carries a concept that cannot be easily mastered by merely studying the definition given in the dictionary, the significance of such data as these may be more readily understood. The learning difficulties involved would, for a considerable number of the group, be very great. Such a wide range of individual differences as is indicated by a coefficient of variability of 37.98, may well be taken into account by those who would avoid placing impossible burdens on inferior students. It seems doubtful that any student could be expected to master a reading assignment in a reasonable time when he is under the necessity of mastering 56 per cent or more of the technical words met, and of forming so large a number of new concepts, along with all of the neural connections incident to the formation of these concepts.⁵ The distribution of scores on these two forms of this test are shown graphically in Figure 2.



⁵Starch, Daniel, *Educational Psychology*, New York, The Macmillan Company, (1923), p. 269.

A study of the results of Form B, given at the end of the term, are strikingly similar to those obtained from Form A. The mean score was 18.05, indicating that the average student would probably know about 47.5 per cent of the technical words met in a textbook assignment in general chemistry. The student at the 75 percentile point would probably have about 1.57 times as large a technical vocabulary as the one at the 25 percentile point. The poorest student would probably have to master about 87 per cent of the technical words met, while the best student would probably already know about 87 per cent of such words.

There are 98 chances in 100 of a real difference greater than zero in favor of the average of the scores on Form B over those on Form A. The measures of central tendency are all higher on Form B, and the measures of variability are all lower on Form B than on Form A. This indicates that there was an apparent improvement in the technical word knowledge of the students as a result of the quarter's study of chemistry.

THE READING FOR DIRECTIONS TEST, SPECIAL TEST NUMBER 3

There is probably little room for question as to whether the ability to read for directions really functions in the study of chemistry. It is recognized that reading for directions and expository reading involve different abilities. This kind of reading ability functions in laboratory work when a student reads directions for performing an experiment and then reacts to these directions. The Reading for Directions Test was constructed to measure this ability. Table III gives a summary of the results on this test.

TABLE III
SUMMARY OF RESULTS BASED ON SPECIAL TEST NUMBER 3

Score	Frequencies, Form A	Frequencies, Form B
41-42	15	5
39-40	39	16
37-38	57	26
35-36	39	37
33-34	33	55
31-32	19	48
29-30	22	28
27-28	23	35
25-26	12	12
23-24	10	15

TABLE III—*Continued*

Score	Frequencies, Form A	Frequencies, Form B
21-22	10	7
19-20	5	9
17-18	3	10
15-16	9	6
13-14	1	1
11-12	1	1
Number	298	311
Range	31	30
Mean	32.79	30.70
Median	36.95	32.27
S. D.	6.67	6.04
Q ₁	27.96	27.96
Q ₃	38.32	35.24
Q	5.18	3.64
S. E. of Av.	.39	.34
V.	20.34	19.67

A study of Table III shows that, on Form A of this test, the average student scored 78.5 per cent of the possible score, while on Form B, the average student scored 73.1 per cent of the possible score. It is seen that the distributions tend strongly to be skewed negatively, and yet the coefficients of variability (20.34 and 19.67) are sufficiently high to indicate that the test was difficult enough to scatter the group widely. The ranges of the two forms of the test (31 and 30), like the other measures of variability, indicate great range in the ability of students to do this kind of reading. The poorest student in the group read Form A of this test with an efficiency of approximately 26.3 per cent, while the best student read with an efficiency of 100 per cent. It will be observed that the measures of variability, as well as the measures of central tendency, are lower on Form B of this test than on Form A, although the two forms of the test showed a high correlation with practically no difference between the means. No reason is assigned for this apparent decrease in the ability of the students to read for directions in the study of chemistry during their first quarter's work in the subject. There is, however, practical certainty of a real difference greater than zero in favor of the average of the scores on Form A over the average on Form B of this test. The higher scores on both forms of this test do not indicate that reading for directions is easier than expositive reading.

THE TEST OF ABILITY TO SELECT THE STEPS NECESSARY IN
SOLVING A CHEMICAL LABORATORY PROBLEM, SPECIAL
TEST NUMBER 4S

The ability to solve a chemical laboratory problem is not necessarily a reading function, and yet it is one that should play a part in the success of a student in general chemistry. This test is intended to measure the ability of a student to start with a definite chemical fact and determine the steps that would have to be carried out in solving a chemical laboratory problem involving that chemical fact or principle. Table IV gives a summary of the results of this test.

TABLE IV
SUMMARY OF RESULTS BASED ON SPECIAL TEST NUMBER 4S

Score	Frequencies, Form A	Frequencies, Form B
38-39	0	1
36-37	1	1
34-35	2	9
32-33	10	18
30-31	5	17
28-29	15	31
26-27	17	27
24-25	15	19
22-23	22	25
20-21	22	24
18-19	27	30
16-17	39	21
14-15	28	14
12-13	17	10
10-11	30	12
8- 9	11	15
6- 7	19	11
4- 5	22	11
2- 3	5	4
0- 1	11	4
Number	318	304
Range	34	35
Mean	16.32	20.53
Median	16.82	21.67
S. D.	8.36	8.62
Q ₁	10.76	15.29
Q ₃	22.68	28.07
Q	5.96	6.38
S. E. of Av.	.47	.49
V.	51.22	42.01

Consideration of Table IV indicates that the average student performed with less than 42 per cent efficiency on Form A of this test. The student at the 25 percentile point would probably score 27.5 per cent of the possible score, while the student at the 75 percentile point would probably score 2.08 times as high. The poorest student in the group scored zero on the test, while the best student scored 84.6 per cent of the possible score. Both the range (34) and the coefficient of variability (51.22) indicate an unusually great difference in ability to select the steps that are necessary in solving chemical laboratory problems.

All measures of central tendency and of dispersion on Form B, which was given at the end of the term, are greater than the corresponding measures on Form A, the coefficient of variability alone being distinctly less on Form B. There is practical certainty of a real difference greater than zero between the mean scores of the two forms of this test in favor of Form B. This indicates an apparent increase in the ability of the students to select the steps necessary to the solution of chemical laboratory problems after studying the subject one quarter. One is impressed with the fact that the variability of the group on either form is so great that a considerable number of the students would find themselves facing an almost impossible task if called upon to perform this kind of work. As stated before, most of the laboratory work done is not of this character, but consists of exercises in which the student merely follows printed directions in the laboratory. It appears, as is shown more fully later in this chapter, that there is a definite relationship between the ability to solve such problems as this test presumes and achievement in chemistry, as measured by the Iowa Training Test. In view of this fact, it might be well for chemistry teachers to look with greater favor upon this type of laboratory work.

THE TEST OF ABILITY TO RANK THE STEPS NECESSARY IN SOLVING
A CHEMICAL LABORATORY PROBLEM, SPECIAL TEST
NUMBER 4R

In solving a chemical laboratory problem it seems evident that the student should be expected not only to select the necessary steps to take in solving the laboratory problem, but also to rank the steps in the order in which they would be carried out in the laboratory. This test is designed to measure this ability. Table V gives a summary of the results obtained from this test.

TABLE V
SUMMARY OF RESULTS BASED ON SPECIAL TEST NUMBER 4R

Scores	Frequencies, Form A	Frequencies, Form B
38-39	0	0
36-37	0	0
34-35	1	2
32-33	1	0
30-31	2	5
28-29	5	5
26-27	10	20
24-25	17	32
22-23	14	28
20-21	24	30
18-19	19	30
16-17	34	30
14-15	26	21
12-13	38	33
10-11	38	26
8- 9	40	21
6- 7	14	11
4- 5	7	5
2- 3	14	4
0- 1	4	1
Number	318	304
Range	33	32
Mean	14.11	17.26
Median	13.68	18.00
S. D.	7.00	6.68
Q ₁	9.23	12.49
Q ₃	19.42	23.14
Q	5.10	5.33
S. E. of Av.	.39	.38
V.	49.61	38.73

A study of Table V shows that the average student in the group scored only about 36.2 per cent of the possible score on Form A of this test, while those in the lower fourth scored not more than 23.6 per cent of the possible score. The student at the 75 percentile point scored about 2.1 times as high as the one at the 25 percentile point. The poorest student in the group was not able to score on this test, while the best student scored 84.6 per cent of the possible score. The measures of central tendency on Form B are all greater than those on Form A, while the variability in the case of Form B is considerably less than that of Form A. The coefficient

of variability in each case (49.61 and 38.73) is very high, indicating the wide range of individual differences of students as to this ability. There is practical certainty of a real difference greater than zero between the means of the two forms of this test in favor of Form B, which indicates that there is an apparent increase in the ability of students to rank the steps that are necessary to the solution of a chemical laboratory problem after one quarter of study of the subject in college. The average student, however, does not seem to be able to perform this type of work with anything approximating satisfactory efficiency.

SPECIAL TESTS NUMBER 1, 2, AND 3 COMBINED AS A BATTERY

Special Tests Number 1, 2, and 3 combined as a battery measure the ability to read expositive chemical literature, mastery of chemical vocabulary, and ability to read for directions in the study of chemistry. Table VI gives a summary of the results from the use of these three tests combined as a battery of special reading tests.

TABLE VI
SUMMARY OF RESULTS BASED ON SPECIAL TESTS NUMBER 1, 2 AND 3

Scores	Frequencies, Form A	Frequencies, Form B
115-119	1	0
110-114	0	0
105-109	6	1
100-104	6	4
95- 99	7	1
90- 94	15	10
85- 89	16	13
80- 84	29	19
75- 79	40	27
70- 74	33	43
65- 69	27	35
60- 64	40	47
55- 59	17	35
50- 54	24	28
45- 49	17	17
40- 44	7	5
35- 39	7	7
30- 34	2	5
25- 29	0	1
Number	294	298
Range	83	78

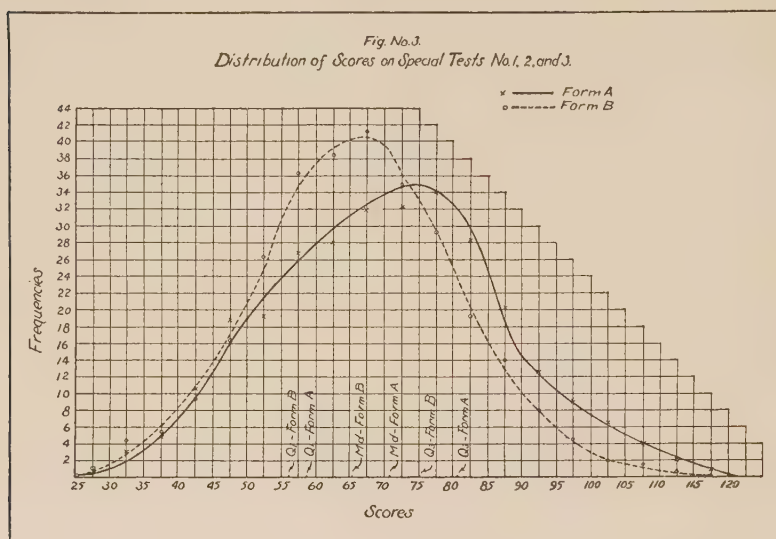
TABLE VI—Continued

Scores	Frequencies, Form A	Frequencies, Form B
Mean	68.49	67.35
Median	70.90	65.57
S. D.	15.93	14.33
Q ₁	57.85	56.64
Q ₃	81.11	75.09
Q	10.63	9.23
S. E. of Av.	.93	.83
V.	23.39	21.27

A study of Table VI shows that the average student in the group performed with an efficiency of about 57 per cent on the Form A of these tests, and 56 per cent on Form B. The student at the 25 percentile point was able to read with an efficiency of about 48 per cent, as measured by Form A of this battery of tests, while the one at the 75 percentile point was able to read with an efficiency almost 2.6 times as great as the poorest. There are only 73 chances in 100 of a real difference greater than zero between the average of the scores on the two forms of this test in favor of the average of Form A. When the three separate measures of reading are considered together there is not certainty of a decrease in the ability of the students to read chemical literature after one quarter of study of the subject in college. This, however, further supports the belief that the ability to read chemical literature is not a simple function, but may be made up of several quite distinct abilities, certain of which may increase or decrease independent of the others during the period when the student is endeavoring to orient himself in the study of a new subject.

The measures of central tendency and of dispersion are all slightly less on Form B than on Form A of this battery of tests. The coefficients of variability (23.39 and 21.27) are both large enough to indicate a wide range of ability of students to perform the types of reading which seem to function especially in the study of chemistry. This indicates that a reading assignment that would be quite reasonable for the better students would be more than twice as difficult for the poorer students in the group to acquire a less perfect mastery of the same subject matter.

The distribution of scores on this battery of tests is shown graphically in Figure 3.



ALL OF THE SPECIAL TESTS ARRANGED AS A BATTERY

The five Special Tests combined as a battery serve to measure the combined abilities considered in this portion of this study. These are summarized for the two forms of this battery in Table VII.

TABLE VII
SUMMARY OF RESULTS BASED ON COMPLETE BATTERY OF SPECIAL TESTS

Scores	Frequencies, Form A	Frequencies, Form B
190-199	0	0
180-189	0	0
170-179	1	0
160-169	7	1
150-159	8	12
140-149	9	9
130-139	21	26
120-129	30	22
110-119	33	48
100-109	41	37
90- 99	38	42
80- 89	36	36
70- 79	31	26
60- 69	25	16
50- 59	7	8

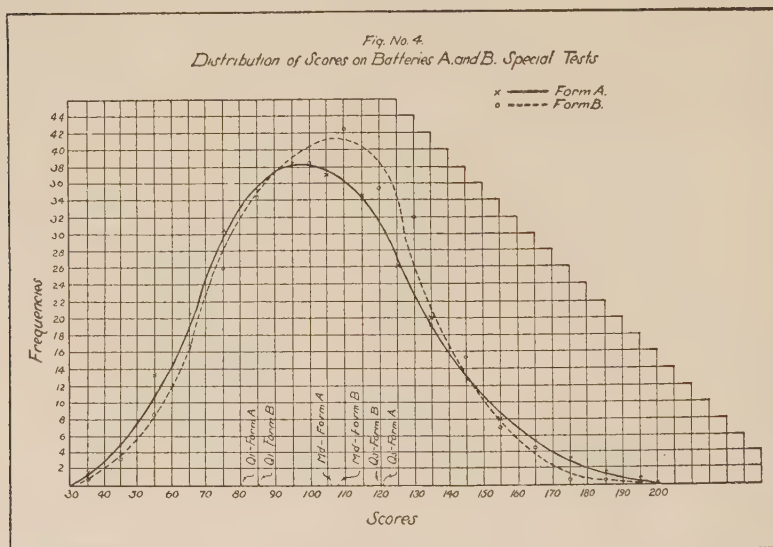
TABLE VII—*Continued*

Scores	Frequencies, Form A	Frequencies, Form B
40-49	9	2
30-39	0	1
Number	296	286
Range	128	135
Mean	101.25	110.28
Median	100.50	103.24
S. D.	27.90	24.36
Q ₁	80.55	85.14
Q ₃	120.69	119.69
Q	20.00	17.27
S. E. of Av.	1.15	1.02
V.	27.55	22.08

A study of Table VII reveals a wide range of individual ability of students in the traits measured by these five tests. On battery A there is a range of 128 points, and on battery B, a range of 135 points out of a total possible score of 198. The average student scored about 51 per cent of the possible score on battery A of these tests. The poorest student scored 22 per cent of the possible score, while the best student scored 3.86 times as high. The student at the 75 percentile point has about 1.5 times the ability, as measured by these tests, as the one at the 25 percentile point. On Form B of these tests the average student scored about 56 per cent of the possible score. The student at the 25 percentile point scored about 43 per cent of the possible score, while the one at the 75 percentile point scored 1.4 times as high.

There is practical certainty of a real difference greater than zero between the means of the two forms of this battery in favor of the mean of Form B, which indicates that there is an apparent improvement of the ability of the students to perform the particular tasks covered by this battery of tests after one quarter's study of chemistry. The measures of central tendency are slightly higher on Form B, while the scores on Form B show slightly less variability. Since there has been discovered such extreme variability on each of the special tests, it is not surprising to find coefficients of variability of 27.55 and 22.08 for the battery.

The distribution of scores on these two batteries of tests is shown graphically in Figure 4.



SPECIAL TESTS NUMBER 4S AND 4R COMBINED AS A BATTERY

Special Tests Number 4S and 4R, which are not reading tests, have been studied separately as measures of the ability of students to select the steps that are necessary in solving a chemical laboratory problem, and to rank those steps after they have been selected. In order to measure the two functions together as a combined ability of solving chemical laboratory problems, the two tests were studied as a battery. Table VIII gives a summary of the results from the two forms of this battery of tests.

TABLE VIII
SUMMARY OF RESULTS BASED ON SPECIAL TESTS 4S AND 4R

Scores	Frequencies, Form A	Frequencies, Form B
75-79	0	0
70-74	1	0
65-69	1	3
60-64	5	12
55-59	11	27
50-54	9	34
45-49	24	40
40-44	27	38
35-39	33	30
30-34	33	36

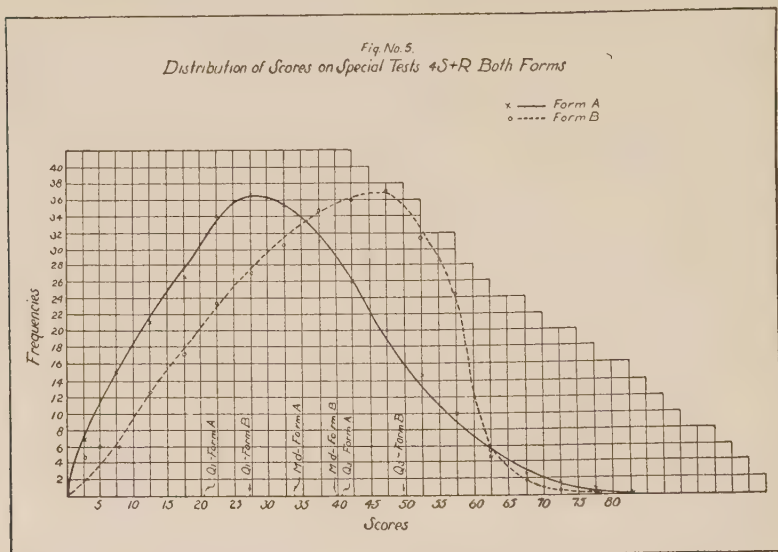
TABLE VIII—*Continued*

Scores	Frequencies, Form A	Frequencies, Form B
25-29	41	27
20-24	36	17
15-19	25	27
10-14	19	9
5- 9	19	4
0- 4	7	5
Number	290	309
Range	70	62
Mean	30.67	38.36
Median	33.48	39.92
S. D.	14.60	14.72
Q ₁	20.35	27.82
Q ₃	40.83	49.84
Q	10.24	11.02
S. E. of Av.	.86	.84
V.	47.58	38.37

According to the data shown in Table VIII, the average student was able to perform with an efficiency of about 39.4 per cent on Form A of these tests. On Form B the average student performed with an efficiency of about 49.2 per cent of the possible score. The results on Form A indicate that the student at the 75 percentile point would probably have about 2 times the ability of the one at the 25 percentile point. On Form B, the student at the 75 percentile point would probably have about 1.78 times the ability of the one at the 25 percentile point. The poorest student was not able to score on this battery of tests, while the best student was able to make nearly 90 per cent of the possible score. There is practical certainty of a real difference greater than zero between the means of the two forms of this battery in favor of the mean of Form B, which indicates apparent improvement in the ability of the students to solve a chemical laboratory problem after one quarter's study of the subject in college.

The coefficients of variability (47.58 and 38.37) indicate that there is great range in the capacity of students to do this kind of work. It probably means that a reasonable assignment which the better students could do fairly well would probably be very difficult for a large group of students.

The distribution of scores on the two forms of this battery of tests is shown graphically in Figure 5.



THE WHIPPLE HIGH SCHOOL AND COLLEGE READING TEST

This test was given in order to measure the general reading ability of the students as it functions outside the field of chemical literature. The use of this test also enables certain comparisons to be made of the present group of students with other groups. Table IX gives a summary of the data obtained from this test which was administered near the beginning of the quarter.

TABLE IX
SUMMARY OF RESULTS BASED ON THE WHIPPLE TEST

Scores	Frequencies
18-18.9	1
17-17.9	2
16-16.9	5
15-15.9	6
14-14.9	9
13-13.9	20
12-12.9	23
11-11.9	27
10-10.9	28
9- 9.9	34
8- 8.9	45
7- 7.9	36

TABLE IX—*Continued*

Scores	Frequencies
6- 6.9	30
5- 5.9	20
4- 4.9	11
3- 3.9	5
2- 2.9	1
1- 1.9	1
0- .9	1
Number	305
Range	17
Mean	9.34
Median	9.15
S. D.	6.25
Q ₁	7.40
Q ₃	12.24
Q	2.42
S. E. of Av.	.35
V.	66.91

A consideration of Table IX shows that the average student read the type of literature found in this test with an efficiency of about 44.7 per cent of the possible score. The exceptionally high coefficient of variability (66.91) is especially significant.

Anderson found in his study of college students of educational psychology, most of whom were juniors and seniors, that his coefficients of variability were 26.8 and 24.8 respectively for the two groups of subjects studied.⁶ The present group of subjects, most of whom were freshmen and sophomores, shows approximately 2.6 times as great a variability as Anderson's. The best reader in this group was able to score 85 per cent of the possible score, while the poorest read with such low efficiency that he was not able to score anything on this test. The student at the 75 percentile point read with an efficiency 1.7 times that of the one at the 25 percentile point. Anderson found that the average of the upper fourth read with an efficiency 2.5 times the average of the lower fourth of the group. The results of this study show similar conditions in the subjects of this study, with the disparity even greater in this group than in Anderson's. The mean of Anderson's group is about 2 points higher on this test than the

⁶Anderson, E. M., *Op. cit.*, p. 21.

mean of this group, while the standard deviation of this group is about twice that found in his study.

Whipple states in his directions for using the Whipple Test that "unless otherwise explicable, a low score in this test (say below the 20th or the 10th percentile point) raises the presumption that the student has distinctly inferior ability in silent reading generally. Unless he can remove this handicap by special training in reading he should be either discouraged from undertaking advanced academic work or should be prepared to follow a reduced schedule of courses with corresponding lengthening of the time needed for graduation."⁷ About 12.8 per cent of these subjects fall within the limits set by Whipple for "distinctly inferior" readers, while about 14 per cent of the present group read with an efficiency that would place them above the 90 percentile point.

THE HOLLEY SENTENCE VOCABULARY SCALES

Reading is based not only on a knowledge of the technical vocabulary of the reading material, but also on ability to command a general vocabulary. Word comprehension is an important part of reading ability. There is no doubt that success in reading depends to a great degree on the ability of the reader to comprehend accurately and quickly the meaning of the words used. For this reason the Holley Sentence Vocabulary Scales were employed in this study, not only to supplement other measures of reading ability, but also to furnish an additional criterion. This test was given shortly after the end of the quarter in which the other tests were given. Table X gives a summary of the results obtained from this test.

TABLE X
SUMMARY OF RESULTS BASED ON THE HOLLEY VOCABULARY SCALES

Scores	Frequencies
69-71	0
66-68	0
63-65	0
60-62	9
57-59	18
54-56	14
51-53	17
48-50	32

⁷Whipple, G. M., Directions for Administering Whipple Reading Test.

TABLE X—*Continued*

Scores	Frequencies
45-47	39
42-44	31
39-41	26
36-38	22
33-35	16
30-32	13
27-29	3
24-26	2
21-23	2
Number	244
Range	41
Mean	44.75
Median	46.39
S. D.	8.47
Q ₁	39.23
Q ₃	49.44
Q	5.10
S. E. of Av.	.54
V.	18.92

Irion found a correlation of 0.68 between word knowledge and reading comprehension.⁸ Anderson's results tend to confirm those of Irion to the effect that word knowledge is a very important item in reading comprehension.⁹ Anderson's correlations approximate those found by Irion. The results of this study show a coefficient of correlation between the Holley Test and the three Special Reading Tests combined of 0.48 and 0.45 on the two forms of the battery of Special Tests. This indicates that there is a significant relationship between general word knowledge, as measured by the Holley Test, and the ability to read chemical literature, as measured by the Special Tests, though that relation is not as high as that found by Irion and Anderson in their studies. This may be due to the influence of the technical vocabulary which possibly may have a more important function in the reading of chemical literature than the technical vocabulary of educational psychology does in reading in that field.

A study of the data in Table X indicates that the average student, as measured by this test, would probably know about 64

⁸Irion, Theo. W. H., *Op. cit.*, p. 48.

⁹Anderson, E. M., *Op. cit.*, p. 53.

per cent of the words which he would meet. The poorest student would probably know about 30 per cent of the words, while the best student would probably have a general vocabulary about 2.96 times as great as this. The range for this test is 41 with a possible score of 70. The range found by Anderson for his groups on this same test was 39 and 34.¹⁰ His means were 54.2 and 52.2, while the mean of this group was 44.75. His coefficients of variability were 15.5 and 13.7 while the coefficient of variability of this group was 18.92. The present group is thus seen to have a wider range of scores than Anderson's, to average 9.45 points lower than his best group, and to show a slightly higher variability than his.

THE IOWA CHEMISTRY TRAINING TEST

In order to measure achievement in chemistry, the Iowa Chemistry Training Test was employed. One form of this test was administered within the first few days of the quarter, and the other was administered within the last few days of the quarter. The results from this test are summarized in Table XI.

TABLE XI
SUMMARY OF RESULTS BASED ON THE IOWA CHEMISTRY TRAINING TEST

Scores	Frequencies, Form A	Frequencies, Form B
170-179	0	0
160-169	0	2
150-159	0	1
140-149	1	1
130-139	2	1
120-129	0	5
110-119	1	5
100-109	0	19
90- 99	5	22
80- 89	4	23
70- 79	8	23
60- 69	18	35
50- 59	23	57
40- 49	35	58
30- 39	52	42
20- 29	87	15
10- 19	59	2
0- 9	28	0
Number	323	311

¹⁰Anderson, E. M., *Op. cit.*, p. 20.

TABLE XI—Continued

Scores	Frequencies, Form A	Frequencies, Form B
Range	140	150
Mean	33.97	63.10
Median	28.56	56.75
S. D.	22.65	26.97
Q ₁	18.94	43.23
Q ₃	44.64	80.54
Q	12.85	18.66
S. E. of Av.	1.26	1.53
V.	66.67	42.74

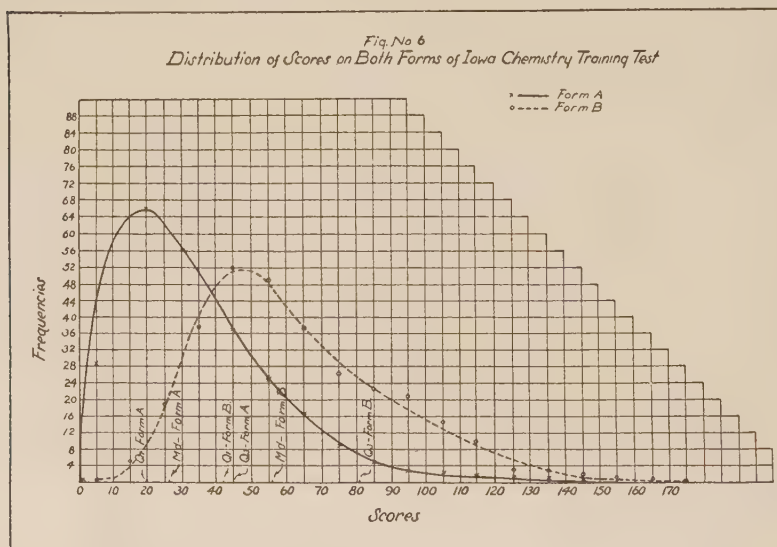
A study of Table XI shows that, on the first form of the test, at the beginning of the term, the mean score was 18 per cent of the possible score. The student at the 75 percentile point probably knew 2.36 times as much chemistry as the one at the 25 percentile point to begin with, while the achievement level of the best student was possibly 141 times that of the poorest.

One of the most striking facts about the results of the first form of the test is the extremely high variability (66.67) of the scores. This may be due, in part at least, to the fact that some of the group had studied chemistry in high school, some had studied physics in high school, some had studied biology, and some had studied general science, while others had studied various combinations of these four science courses.¹¹ At the same time there were a few students in the group which had never studied any science before either in high school or in college. In any case, the data would seem to indicate that there is a serious problem for the college chemistry teacher who is unable to section his group on the basis of ability to achieve in this subject, without his adopting an attitude of indifference toward the individual student and his problems.

The results of the second form of this test show that the achievement level of the group, as indicated by the mean scores on the test, had nearly doubled, while most of the measures of dispersion had increased. At the beginning of the term, about 68 per cent of the group would most probably score between 11.32 and 56.62, while at the end of the term, about 68 per cent would most prob-

¹¹This problem is considered later under the heading, "The Influence of the Science Studied in the High School."

ably score between 36.13 and 90.07. The coefficient of variability at the beginning was 1.56 times as great as it was at the end of the term. At the end of the term the range of scores was from 10 to 163, indicating that the best student had an achievement level, as measured by this test, about 16 times as high as that of the poorest. The distribution of scores on the two forms of this test are shown graphically in Figure 6.



The norms of this test are based on either a year of high school chemistry or one semester of college chemistry. The mean score, as well as the standard deviation of the group at the end of the quarter, was slightly lower than the norm. The 75 percentile point of the present group was considerably lower than the norm, while the 25 percentile point was practically the same as the norm.

TEACHERS' MARKS

No effort was made to prescribe any uniform method by which each of the teachers cooperating in this study should determine the final mark of each student. For convenience in statistical treatment, marks for each student not reported in percentages were translated accordingly from the letter grades given. In the two institutions which used the semester basis the instructors gave the tests as scheduled, and determined the standing of each student

as of the date of closing of the quarter, just as if they had been on the quarter basis. Table XII gives a summary of the data from a study of the distribution of teachers' marks.

TABLE XII
SUMMARY OF RESULTS BASED ON TEACHERS' MARKS

Scores	Frequencies
97-99	4
94-96	14
91-93	14
88-90	10
85-87	72
82-84	16
79-81	57
76-78	14
73-75	14
70-72	19
67-69	8
64-66	7
61-63	8
58-60	10
55-57	6
52-54	5
49-51	4
46-48	2
43-45	0
40-42	2
37-39	0
34-36	1
Number	314
Range	64
Mean	78.29
Median	80.58
S. D.	11.29
Q ₁	73.48
Q ₃	86.48
Q	6.50
S. E. of Av.	.64
V.	14.42

A study of Table XII shows that the mean score of the group was 78.29 per cent. About 68 per cent of the group would most probably score between 69 and 92, and about 50 per cent of the group would most probably score between 74 and 87 per cent. Of the remaining 50 per cent, 28.3 per cent would probably score below 74. The results shown in this table indicate that the best

student in the group has an achievement level in chemistry about 2.82 times as great as the poorest.

INTELLIGENCE QUOTIENTS

There seems to be little cause for doubt that intelligence examinations have some value in predicting success in college. Strickland found that there is a fairly high correlation between intelligence and success in most college subjects, including science, agriculture, and engineering.¹² (Strickland also found that "the General Science Division gets results least commensurate with the ability of its students.") Powers found that there is a close relationship between intelligence and marks assigned those below the median in intelligence quotients.¹³ Broom and Lawson state that "the findings of the Thorndike Intelligence Examination must be accepted at present as the best criterion for predicting success in the study of college physical science during the first semester."¹⁴ Hurd found that the correlation between the intelligence quotients and success in physics is high.¹⁵ Breed found that "intelligence is by far the most important factor in determining educational achievement."¹⁶

While these authors agree substantially on the value of the intelligence examination, the fact must not be overlooked that there are investigators who do not share these views. Bridges,¹⁷ Grauer and Root,¹⁸ and Wolf¹⁹ reached conclusions to the effect that intelligence scores, alone, do not form a very efficient basis for prediction because of the other factors which are involved. This study attempts to determine, with the group available, the extent

¹²Strickland, Vivan L. *Relative Levels of Intelligence in College and High School*, Dissertation, University of Nebraska, 1925, pp. 88-89.

¹³Powers, S. R., "A Correlation Between Measures of Mental Ability and Measures of Achievement in Chemistry," *School Science and Mathematics*, Vol. XXVIII, (December 1928), p. 985.

¹⁴Broom, M. E. and Lawson, J. W., "Predicting Success in First Semester Courses in Physical Sciences," *School Science and Mathematics*, Vol. XXIX, (1929), p. 626.

¹⁵Hurd, A. W., "The Intelligence Quotient as a Prognosis of Success in Physics," *School Review*, Vol. XXXIV, (1926), pp. 123-128.

¹⁶Breed, F. S., "Shall We Classify Pupils by Intelligence Tests?" *School and Society*, Vol. XV, (1922), pp. 406-409.

¹⁷Bridges, J. W., "The Value of Intelligence Tests in Universities," *School and Society*, Vol. XV, (1922), p. 295.

¹⁸Grauer, David and Root, W. T., "The Thorndike Intelligence Test and Academic Grades," *Journal of Applied Psychology*, Vol. XI, (1927), pp. 317-318.

¹⁹Wolf, Milton G., "The Relation Between Degrees of Intelligence and Success in the Study of Chemistry," *Journal of Chemical Education*, Vol. V, (1928), p. 82.

to which intelligence, as measured by the Otis Test, does correlate with success in chemistry.

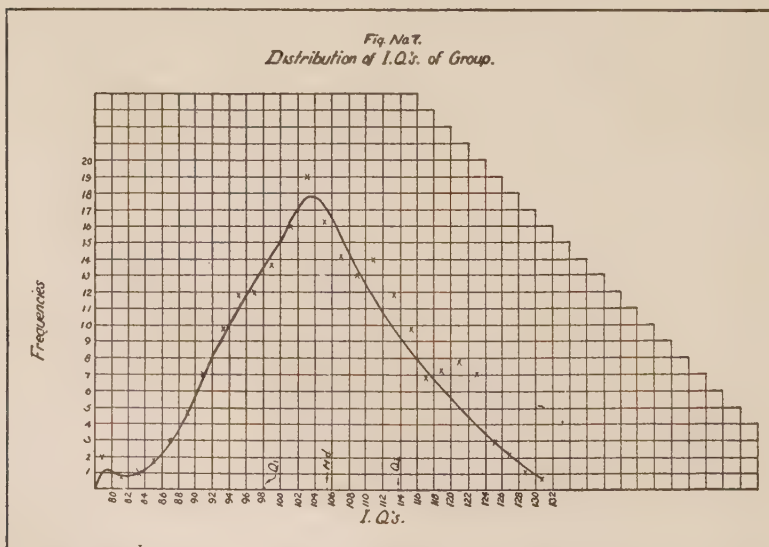
Table XIII gives a summary of the data obtained from the use of the Otis Self-Administering Test of Mental Ability, Higher Examination, Form C.

TABLE XIII
SUMMARY OF RESULTS BASED ON THE OTIS INTELLIGENCE TEST

Scores (Intelligence Quotients)	Frequencies
131-132	1
129-130	1
127-128	2
125-126	3
123-124	4
121-122	14
119-120	5
117-118	7
115-116	8
113-114	14
111-112	13
109-110	15
107-108	8
105-106	20
103-104	21
101-102	16
99-100	11
97- 98	14
95- 96	10
93- 94	11
91- 92	8
89- 90	4
87- 88	2
85- 86	3
83- 84	0
81- 82	0
79- 80	2
Number	217
Range	52
Mean	105.94
Median	105.67
S. D.	10.33
Q ₁	98.75
Q ₃	113.58
Q	7.42
S. E. of Av.	.70
V.	9.79

A study of Table XIII shows that the mean intelligence quotient of the group is 105.94, with a standard deviation of 10.33. Anderson found that his group, consisting almost entirely of juniors and seniors, had a mean intelligence quotient of 115.80, with a standard deviation of 9.40.²⁰ The student with the lowest intelligence quotient would certainly be more or less seriously handicapped in attempting to keep pace with students in the higher group in intelligence. The best student in the group ranks 1.66 times as high in intelligence as the poorest. Anderson found that the coefficients of variability of his two groups were 8.0 and 7.6, while that of the present group was found to be 9.79. This indicates that this group averaged not only slightly lower in intelligence than Anderson's, but that the variability is somewhat higher in the present group.

The distribution of scores on this test is shown graphically in Figure 7.



The wide range in the intelligence quotients of this group indicates that the teacher of chemistry should be concerned about the student who ranks in the lower fourth of the distribution, since it seems to be fairly well established that intelligence tests do measure something which functions in the learning pro-

²⁰Anderson, E. M., *Op. cit.*, p. 16.

cess. It is shown later in this chapter that the coefficient of correlation between intelligence quotients and chemistry training test scores for the group studied is high enough to be significant.

SUMMARY OF THE RANGES OF VARIOUS TESTS

For convenience of comparison, Table XIV presents a summary of the ranges of the various tests and batteries of tests used in this study.

TABLE XIV
SUMMARY OF RANGES OF TESTS USED

Test	Possible Score	Highest Score	Lowest Score	Range
Test Number 1A.....	40	39	2	37
Test Number 1B.....	40	37	2	35
Test Number 2A.....	38	33	5	28
Test Number 2B.....	38	36	5	30
Test Number 3A.....	42	42	11	31
Test Number 3B.....	42	41	11	30
Test Number 4AS.....	39	34	0	34
Test Number 4BS.....	39	35	0	35
Test Number 4AR.....	39	33	0	33
Test Number 4BR.....	39	34	2	32
Tests Number 1, 2, 3, Form A...	120	115	32	83
Tests Number 1, 2, 3, Form B...	120	106	28	78
Battery A, Special Tests.....	198	168	40	128
Battery B, Special Tests.....	198	166	31	135
Whipple Test.....	20	17	0	17
Holley Test.....	70	62	21	41
Otis Intelligence Test.....	133+	131	79	52
Iowa CT1-A.....	188	141	1	140
Iowa CT1-B.....	188	163	10	158
Teachers' Marks.....	100	99	35	64
Tests Number 4AS, 4BS.....	78	70	0	70
Tests Number 4AR, 4BR.....	78	66	4	62

DISTRIBUTION OF STUDENTS IN UPPER AND LOWER FOURTHS BY COLLEGES

Table XV is presented to show the percentages of students in the upper and lower fourths of the distribution by colleges.

College E was omitted from all portions of this study involving intelligence quotients because these data were not available for that college.

TABLE XV
PERCENTAGE DISTRIBUTION OF STUDENTS ACCORDING TO COLLEGES

Test	College A	College B	College C	College D	College E	Average
Pct. below Q ₁ , Whipple . .	35.6	21.4	33.3	41.4	33.3	35.0
Pct. above Q ₃ , Whipple . .	11.0	10.7	11.9	19.0	14.3	13.5
Pct. below Q ₁ , Holley . . .	21.9	39.3	23.5	14.3	30.8	25.9
Pct. above Q ₃ , Holley . . .	15.6	25.0	25.0	35.7	26.0	25.6
Pct. below Q ₁ , I. Q's	40.0	25.0	19.3	23.7		27.0
Pct. above Q ₃ , I. Q's	20.0	21.4	21.5	28.6		22.9
Pct. below Q ₁ , Battery A .	20.0	22.5	32.2	22.2	26.6	24.7
Pct. above Q ₃ , Battery A .	15.5	22.5	15.8	43.3	12.2	21.9
Pct. below Q ₁ , Battery B .	13.3	19.3	20.4	13.7	22.3	17.8
Pct. above Q ₃ , Battery B .	22.2	22.5	14.7	28.5	19.2	21.6
Pct. below Q ₁ , CT1-A . . .	4.4	32.2	30.1	22.2	22.3	22.2
Pct. above Q ₃ , CT1-A . . .	31.1	22.2	20.0	22.2	18.1	22.7
Pct. below Q ₁ , CT1-B . . .	28.9	22.5	19.3	43.1	22.2	27.0
Pct. above Q ₃ , CT1-B . . .	15.5	22.2	22.1	19.0	26.5	21.1
Pct. below Q ₁ , Teachers'						
Marks	22.2	12.9	60.2	7.9	3.1	21.3
Pct. above Q ₃ , Teachers'						
Marks	24.4	24.4	4.2	7.9	3.1	17.4

A study of Table XV indicates that although there is considerable variation in the colleges studied as to the percentage of students in the upper and lower fourths on the various tests, the average is still fairly satisfactory in practically every case. It may be noted that College D had the highest percentage of students in the upper fourth in intelligence quotients, and also the highest percentage in the upper fourth on the Whipple Test, the Holley Test, and in both batteries of the Special Tests. The institution which ranked lowest in intelligence quotients, however, ranked lowest only on the second Chemistry Training Test. The institution that scored highest on Battery A of the Special Tests also scored highest on Battery B, and next to the highest on the second Chemistry Training Test. The institution that ranked lowest on Battery A of the Special Tests also ranked lowest on Battery B.

CHEMICAL ARITHMETIC

This study has made no attempt to discover the relationship between the various mathematical skills and achievement in chemistry. That is a proper subject for another study. Since

the Iowa Chemistry Training Test has one part devoted to chemical arithmetic, these results are summarized.

Table XVI gives a summary of the data from Part 4 of the second Iowa Chemistry Training Test.

TABLE XVI
SUMMARY OF RESULTS ON PART 4,
(CHEMICAL ARITHMETIC), CT1-B TEST

Scores	Frequencies
45-49	1
40-44	5
35-39	6
30-34	15
25-29	19
20-24	53
15-19	66
10-14	71
5- 9	52
0- 4	23
Number	311
Range	48
Mean	16.65
Median	15.72
S. D.	8.95
Q ₁	5.19
Q ₃	16.91
Q	5.81
S. E. of Av.	.51
V.	33.10

In the arithmetical part of this test there are 12 problems, each involving the application of arithmetical principles to the solution of chemical problems. Each problem correctly solved counts four points, giving a total possible score of 48. The mean score of the group was 16.65. The student at the 75 percentile point performed with an efficiency of about 3.27 times the one at the 25 percentile point on this part of the test. The poorest student in the group was not able to solve a single problem correctly, while the best student was able to solve all of the problems. About 7.4 per cent of the group were unable to solve more than one problem, while 8.25 per cent were able to solve 8 problems or more in the time allotted for this part of the test. The coefficient of variability (33.1) indicates a wide range of ability of the students to

apply arithmetical principles to the solution of problems arising out of chemistry situations. This study does not attempt to determine whether this failure to solve problems in chemical arithmetic is due to a lack of mastery of arithmetical skills, or to a lack of proper conditioning of the reactions, so that principles which are known to the student fail when it comes to applying them in a new field. In either case such a variation in ability indicates the difficulty with which large numbers of college students are confronted.

2. A STUDY OF ACHIEVEMENT IN GENERAL CHEMISTRY AS RELATED TO PERFORMANCE ON OTHER TESTS USED

Individual differences of students in achievement in chemistry, as measured by the Iowa Chemistry Training Tests, and the differences in the abilities which function in achievement in chemistry, as measured by the Special Tests, the Holley Test, the Whipple Test, and the Otis Test, have been considered from the standpoint of measures of central tendencies and dispersion. This part of the study considers achievement in chemistry as it is related to these same measures of learning ability.

Table XVII shows the coefficients of correlation of the first Chemistry Training Test scores with the scores on all of the other tests used.

TABLE XVII
CORRELATION OF CT1-A SCORES WITH OTHER TEST SCORES

Test	$r \pm P. E.$	
Special Test Number 1A	0.55	.025
Special Test Number 2A	0.67	.022
Special Test Number 3A	0.34	.035
Special Test Number 4AS	0.55	.027
Special Test Number 4AR	0.44	.032
Special Tests Number 1, 2, and 3, Form A	0.58	.026
Special Tests, Battery A, complete	0.69	.021
Special Tests Number 4AS and 4AR	0.57	.025
Whipple Reading Test	0.29	.036
Holley Vocabulary Test	0.37	.038
Intelligence Quotients	0.47	.035

A study of Table XVII shows that achievement in general chemistry, as measured by the Iowa Chemistry Test, bears a positive relationship to each of the other measures used. The Chemistry

Training Test and the Special Tests have correlations ranging from 0.34, in the case of Test Number 3A, to 0.69 for the entire battery. These correlations are high enough, with the exception of Test Number 3A, to indicate a significant relationship between these traits.

Garrett states that "a coefficient of correlation of 0.00 to 0.20 denotes indifferent or negligible relation; from 0.20 to 0.40 denotes low correlation, present but slight; from 0.40 to 0.70 denotes substantial or marked relationship; and from 0.70 to 1.00 denotes high relationship."²¹ In this study the above classification of coefficients of correlation is used. The almost uniformly marked relationship of the Special Tests with the Chemistry Training Test indicates that the traits measured by the Special Tests probably function to a considerable extent in determining scores made by students on the Chemistry Training Test.

The correlation of the Chemistry Training Test with either the Whipple Test or the Holley Test is low (0.29 and 0.37). This would seem to indicate that there is a considerably closer relationship between chemistry achievement, as measured by the Iowa Training Test, and the abilities measured by the Special Tests than there is between chemistry achievement and the abilities measured by either the Whipple Test or the Holley Test. It would seem to indicate, also, that reading of chemical literature is probably a rather specific function which may be more accurately measured by the Special Tests than by any of the other tests used in this study.

The coefficient of correlation between intelligence quotients and chemistry achievement, as measured by the Iowa Test, is 0.47, which is lower than the correlation of chemistry achievement with scores on expositive reading, chemistry vocabulary, or either of the batteries of Special Tests. This indicates that there is a significant and positive relationship between intelligence and achievement in chemistry, but that this relationship is not as marked as that between achievement in chemistry and these other traits. It appears, from the use of simple correlations, that the Special Tests constitute a better basis for predicting probable success in general chemistry than any of the other measures used.

Battery A of the Special Tests, correlated with the Chemistry Training Test, gives a predictive index of 27.62, according to the

²¹Garrett, H. E., *Statistics in Psychology and Education*, New York, Longmans Green and Company, (1926), p. 298.

method given by Hull.²² The intelligence quotients correlated with the Chemistry Training Test scores give a predictive index of 11.73. Hull states that the limits of efficiency of modern tests for prognostic purposes are, in terms of the predictive index, from 13 to 30, and that our present measuring instruments will scarcely give a higher predictive index than 30. It might be noted, in this connection, that the correlation of the Chemistry Training Test with the Chemistry Vocabulary Test alone has a predictive index almost as high as that of the entire battery of Special Tests, and considerably higher than any of the other single tests.

These facts agree with the observation that 64.4 per cent of those who placed in the upper fourth of the group on either Battery A or Battery B of the Special Tests, or both, were also in the upper fourth in one or both of the Chemistry Training Tests; and that 57.3 per cent of those who placed in the lower fourth in either or both of the batteries of Special Tests, were also in the lower fourth in either or both of the Chemistry Training Tests.

COEFFICIENTS OF CORRELATION OF SCORES ON THE SECOND CHEMISTRY TRAINING TEST WITH SCORES ON OTHER TESTS

At the end of the quarter the second form of the Iowa Chemistry Training Test, as well as the B forms of the Special Tests, was given. Table XVIII shows the coefficients of correlation of these measures with scores made on the second Chemistry Training Test. The results of this part of the study compare favorably with those obtained from Table XVII.

TABLE XVIII
CORRELATION OF CT1-B SCORES WITH OTHER MEASURES

Test	$r \pm P. E.$	
Special Test Number 1B.....	0.55	0.027
Special Test Number 2B.....	0.60	0.025
Special Test Number 3B.....	0.18	0.037
Special Test Number 4BS.....	0.41	0.033
Special Test Number 4BR.....	0.41	0.033
Special Tests Number 1 2, and 3, Form B.....	0.56	0.027
Special Tests, Battery B.....	0.54	0.027
Special Tests Number 4BS and 4BR.....	0.39	0.033
Whipple Reading Test.....	0.33	0.035
Holley Vocabulary Test.....	0.34	0.035

²²Hull, C. L., "The Correlation Coefficient and Its Prognostic Significance," *Journal of Educational Research*, Vol. XV, (1927), pp. 327-328.

A study of Table XVIII indicates that the correlations of the scores on the various other measuring instruments with scores made on the second Iowa Chemistry Training Test are all positive, and, in the case of the Special Tests, all high enough to denote significant relationship, (0.41 to 0.60) with the single exception of Special Test Number 3B (0.18). It is observed that the tests of highest predictive value are Special Tests Number 1B and 2B, as was observed in Table XVII for the A forms of the same tests. The Whipple Test, the Holley Test, and Special Test Number 3B again are found to have the lowest predictive value.

The coefficients of correlation of the B forms of these tests support the conclusion already drawn from the correlations of the A forms of the same tests to the effect that reading in the field of chemistry is a rather specific function which may not be accurately measured by instruments intended to measure general reading ability in other fields. The results with the B forms of the tests also indicate that the ability to solve a chemical laboratory problem bears a substantial relationship (0.41) to achievement in chemistry as measured by the Iowa Chemistry Training Test.

CORRELATION OF TEACHERS' MARKS WITH OTHER TEST SCORES

Since teachers' marks constitute another measure of achievement in chemistry, correlations between these marks, given at the end of the quarter, and the scores on the B forms of the Special Tests were made. Table XIX gives the coefficients of correlation between teachers' marks and the scores made on the B forms of the various tests used to measure the basic abilities.

TABLE XIX
CORRELATION OF TEACHERS' MARKS WITH SCORES ON OTHER TESTS

Test	$r \pm P. E.$	
Special Test Number 1B.....	0.45	0.031
Special Test Number 2B.....	0.41	0.033
Special Test Number 3B.....	0.09	0.039
Special Test Number 4BS.....	0.40	0.033
Special Test Number 4BR.....	0.33	0.033
Special Tests Number 1, 2, and 3, Form B.....	0.41	0.037
Special Tests, Battery B.....	0.47	0.031
Special Tests Number 4BS and 4BR.....	0.37	0.033
Holley Vocabulary Test.....	0.13	0.042
Whipple Reading Test.....	0.25	0.036
Intelligence Quotients.....	0.26	0.042

All of the coefficients of correlation in Table XIX are positive, but Special Tests Number 1B, 2B, and 4BS are the only ones that bear a significant relationship to teachers' marks. It will be noted by referring to Table XVIII that the coefficients of correlation between each of the Special Tests and the scores on the Iowa Chemistry Training Test are higher than the coefficients of correlation of corresponding tests with teachers' marks.

Both the battery of Special Reading Tests and the entire battery of Special Tests have coefficients of correlation with teachers' marks high enough to denote substantial relationship (0.41 and 0.47), but lower than the corresponding coefficients of correlation with scores made on the Iowa Chemistry Training Test (0.56 and 0.54). This would tend to show that the Iowa Chemistry Training Test measures whatever is measured with greater consistency than do the teachers' marks.

CORRELATION OF THE SPECIAL TESTS WITH INTELLIGENCE QUOTIENTS

Form A of the Special Tests were correlated with intelligence quotients, as determined by the Otis Intelligence Test. These relationships are shown in Table XX.

TABLE XX
CORRELATION OF INTELLIGENCE QUOTIENTS WITH OTHER TEST SCORES

Test	$r \pm P. E.$	
Special Tests Number 1, 2, and 3, Form A.....	0.70	.024
Special Tests, Battery A.....	0.70	.024
Special Tests Number 4AS and 4AR.....	0.52	.036
Whipple Reading Test.....	0.64	.026
Holley Vocabulary Test.....	0.56	.033

A study of Table XX shows that both Special Tests Number 1, 2, and 3, and Battery A of the Special Tests correlate high with intelligence as measured by the Otis Test (0.70). Special Tests Number 4AS and 4AR also bear a substantial relationship to intelligence quotients (0.52). The correlation between the Whipple Test scores and intelligence quotients (0.64) is quite comparable with the corresponding correlations found by Anderson.²³ His correlations were 0.67 and 0.68 for his two groups on the same

²³Anderson, E. M., *Op. cit.*, p. 32.

two traits. The correlation in this study, likewise, between the Holley Test and intelligence quotients (0.56) compares very favorably with Anderson's correlations of 0.57 and 0.63 for his two groups on the same traits.

A STUDY OF THE CORRELATION OF WHIPPLE TEST SCORES WITH THOSE ON OTHER TESTS

A study of the Special Tests would not be complete without some consideration of the relationship of scores made on these tests to scores made on the Whipple Test and the Holley Test. Table XXI gives the coefficients of correlation of the Special Test scores with those made on the Whipple Reading Test.

TABLE XXI
CORRELATION OF WHIPPLE TEST SCORES WITH THOSE ON OTHER TESTS

Test	r ± P. E.
Special Test Number 1A.....	0.56 .027
Special Test Number 2A.....	0.52 .028
Special Test Number 3A.....	0.51 .029
Special Test Number 4AS.....	0.53 .029
Special Test Number 4AR.....	0.49 .029
Special Tests Number 1, 2, and 3, Form A.....	0.62 .026
Special Tests, Battery A.....	0.58 .028
Special Tests Number 4AS and 4AR.....	0.43 .033
Holley Test.....	0.68 .026

Table XXI shows that the Special Tests, whether taken singly or by batteries, bear a marked relationship to the Whipple Test scores. The correlations range from 0.43, for Special Tests Number 4AS and 4AR, to 0.62 for Special Tests Number 1, 2, and 3, Form A. The correlation between the Holley Test scores and the Whipple Test scores (0.68) is very similar to the corresponding correlation found by Anderson²⁴ (0.61 and 0.71) between his tests and these same measures.

A STUDY OF THE CORRELATION OF THE HOLLEY TEST SCORES WITH THOSE ON OTHER TESTS

A study of the scores made on the B form of the Special Tests with scores made on the Holley Vocabulary Test is presented in Table XXII.

²⁴Anderson, E. M., *Op. cit.*, p. 32.

TABLE XXII
CORRELATION OF HOLLEY TEST SCORES WITH SCORES ON OTHER TESTS

Tests	$r \pm P. E.$	
Special Test Number 1B.....	0.49	0.030
Special Test Number 2B.....	0.40	0.034
Special Test Number 3B.....	0.31	0.039
Special Test Number 4RS.....	0.44	0.034
Special Test Number 4BR.....	0.43	0.034
Special Tests Number 1, 2, and 3, Form B.....	0.45	0.032
Special Tests, Battery B.....	0.56	0.030
Special Tests Number 4BS and 4BR.....	0.46	0.032
Whipple Reading Test.....	0.68	0.026

Table XXII shows that the coefficients of correlation of all of the tests, except Special Test Number 3B, are high enough to denote a significant relationship (0.40 to 0.49). Scores on the three batteries of Special Tests also bear a significant relationship to scores on the Holley Test (0.45 to 0.56). The highest relationship found between a single test and the Holley Test is that in the case of Special Test Number 1B (0.49). Because of the fact that general vocabulary is involved to some extent in expository reading in the field of chemistry, it is possibly to be expected that there would be a closer relationship between expository reading in chemistry and general word knowledge than between general word knowledge and the traits measured by the other tests.

In order to test the relationships represented by these coefficients of correlation for linearity, the Blakeman test was used. Random samples of the coefficients of correlation were taken and subjected to this test, and all of these were found to be linear. Then a number of others which, from the appearance of their scatter diagrams, looked as if they might possibly be non-linear were similarly tested. All of these were found to be linear. It was concluded, therefore, that all of the relationships represented by coefficients of correlation in this study were linear.

THE APPLICATION OF PARTIAL CORRELATION TECHNIQUES

The simple coefficients of correlation are made the basis of a study of the relationships of achievement in chemistry, as measured by the Iowa Chemistry Training Test, and by teachers' marks, to the learning abilities measured by the Special Tests, when the influence of the other factors is held constant.

A SERIES OF THREE-VARIABLE STUDIES INVOLVING THE CHEMISTRY TRAINING TEST

The coefficients of correlation of the second Chemistry Training Test scores with intelligence quotients (0.49) is reduced to 0.11 when the influence of the traits measured by the battery of Special Tests is held constant by partial correlation. The coefficient of correlation of the Chemistry Training Test scores with scores made on the Whipple Test (0.33) is reduced to -0.03 when the influence of the traits measured by the Special Tests is eliminated. The coefficient of correlation of scores on the Chemistry Training Test with scores made on the battery of Special Tests (0.61) is reduced to 0.55 when the influence of general reading ability is eliminated by partial correlation. The coefficient of correlation of scores on the Chemistry Training Test with intelligence quotients (0.49) is lowered to 0.38 when the influence of general reading ability is eliminated. These facts seem to indicate the persistent marked relationship between the abilities measured by the Special Tests and achievement in chemistry, as measured by the Iowa Chemistry Training Test, even when the influence of the other variables is eliminated one at a time.

A FOUR-VARIABLE STUDY FOR PREDICTING CHEMISTRY TRAINING TEST SCORES

In this study the following factors are considered: (1) achievement in general chemistry, as measured by the second Iowa Chemistry Training Test; (2) the abilities measured by Battery A of the Special Tests; (3) general reading ability, as measured by the Whipple Test; and (4) intelligence quotients, as measured by the Otis Test.

The simple coefficient of correlation of the Chemistry Training Test scores with the battery of Special Tests (0.61) is reduced to 0.44 when the influence of general reading ability and intelligence is eliminated by partial correlation. This decrease of 0.17 in the coefficient of correlation shows that the traits held constant bear some relationship to chemistry achievement. It is equally obvious that there is still a persistent significant relationship between chemistry achievement and the abilities covered by the Special Tests, even after the influence of general reading ability and intelligence is eliminated by partial correlation.

The coefficient of correlation between chemistry achievement and general reading ability, as measured by the Whipple Test, (0.33) is reduced to -0.08 when the influence of the Special Tests and intelligence is eliminated. The coefficient of correlation between chemistry achievement and intelligence (0.49) is reduced to 0.13 when the influence of the Special Tests and the Whipple Test is eliminated. These facts tend to support the conclusion that the abilities covered by the Special Tests are more closely related to achievement in chemistry, as measured by the Iowa Training Test, than are the other measures used.

By the use of the regression equation several predictions of Chemistry Training Test scores were made for students ranging from distinctly superior to inferior.

Case 1 is selected at random from a group of superior students. As calculated from the regression equation, this student's most probable score on the second Chemistry Training Test would be 103. The standard error of estimate was found to be 21.18, which means that his actual score would, in about 68 cases in 100, fall between 82 and 125, although there would be about 16 chances in 100 that the score would be below 82, and 16 chances in 100 that it would be above 125. The score made by this student in this test was 159. This indicates that the predicted score for a superior student will probably fall below the actual score.

Case 2 was selected at random from a group of inferior students. As calculated from the regression equation, this student's predicted most probable score was 29, while the actual score earned by this student on this test was 38. The most probable score in this case falls well within the limits of the standard error of estimate.

Case 3 is selected at random from a group of medium students. The score predicted from the regression equation for this student as the most probable score on this test was 66, while the actual score earned was 59. This, again, is well within the limits of the standard error of estimate. These facts seem to indicate that the regression equation enables one to predict with fair accuracy in the case of medium and inferior students, but that the actual score, in the case of superior students generally falls above the upper limit of the standard error of estimate.

The coefficient of multiple correlation, which may be considered to be the coefficient of correlation between the predicted score and the actual score, was found, in this case, to be 0.62. This

indicates a marked relationship between predicted score and actual score.

A SERIES OF FOUR-VARIABLE STUDIES INVOLVING TEACHERS' MARKS

Another partial correlation study was made in which the following variables were considered: (1) teachers' marks; (2) Battery A of the Special Tests; (3) the Whipple Test; and (4) intelligence quotients.

The simple coefficient of correlation between teachers' marks and scores made on Battery A of the Special Tests (0.44) is reduced to 0.33 when the influence of the general reading ability and intelligence is eliminated. The coefficient of correlation between teachers' marks and the Whipple Test scores (0.25) is reduced to -0.04 when the influence of the other two factors is eliminated. The coefficient of correlation of teachers' marks with intelligence quotients (0.26) is reduced to 0.09 when the influence of the other two factors is eliminated. These facts indicate that the abilities measured by the Special Tests bear a closer relationship to chemistry achievement, as measured by teachers' marks, than either general reading ability or intelligence.

By the use of the regression equation several predictions of teachers' marks were made for students ranging from quite superior to inferior.

Case 1 is selected at random from a group of superior students. It was found that the predicted mark in this case was 92, while the actual mark received by this student was 95. The standard error of estimate was 10.1, which means that the predicted most probable mark is well within the limits of the standard error of estimate.

Case 2 is selected at random from a group of inferior students. The predicted most probable score was 68, while the actual mark received by the student was 60. This, also, is well within the standard error of estimate.

Case 3 is selected at random from a group of medium students. The predicted most probable score in this case was 79, while the actual mark received by the student was 84. This predicted mark is also well within the limits of the standard error of estimate.

It appears, from the foregoing facts, that the most probable teachers' marks may be predicted with reasonable accuracy by the use of the instruments employed in this study. It also appears, as has already been stated, that the most valuable instruments used in this study for prediction are the Special Tests.

The coefficient of multiple correlation in this study was found to be 0.45. This indicates that there is a fairly significant relationship between the predicted teachers' mark and the actual teachers' mark.

3. A STUDY OF ACHIEVEMENT IN GENERAL CHEMISTRY AS INFLUENCED BY OTHER FACTORS

A study of the factors which might influence success in general chemistry in college should include as a minor consideration such factors as the size of the high school from which the student graduated, the type of school in which the student learned to read, the sciences studied in high school, whether chemistry is taken as an elective or as a requirement, and sex. These items follow in order.

THE INFLUENCE OF THE SIZE OF HIGH SCHOOL FROM WHICH THE STUDENT GRADUATED

In considering the question of the possible influence which the size of high school from which the student graduated might have upon success in college chemistry, high schools with 20 or more teachers were arbitrarily classed as large high schools. Those with between 10 and 19 teachers, inclusive, were classed as middle-sized high schools, and those having 9 teachers or fewer were classed as small high schools. Table XXIII gives a summary of the data bearing on this point.

TABLE XXIII
CHEMISTRY TRAINING SCORES ON BASIS OF SIZE OF HIGH SCHOOL

	Large H. S.	Middle H. S.	Small H. S.	Whole Group
Mean of CT1-A.....	38.80	34.46	29.97	33.97
Mean of CT1-B.....	67.80	58.42	55.02	63.10
Improvement.....	29.00	23.96	25.05	29.13
V. of 1st CT Scores.....	68.72	69.83	64.23	66.67
V. of 2nd CT Scores.....	41.95	40.58	43.07	42.74

The data in Table XXIII indicate that the students who graduated from the large high schools average higher on both chemistry training tests than those from either of the other types of schools. The chances are about 93 in 100 of a reliable difference greater than zero in favor of those who graduated from the large high schools over the average of the entire group studied, as indicated by the scores made on the second Iowa Chemistry Training Test. There are 86.5 chances in 100 of a reliable difference greater than zero in favor of the average of the whole group over those who graduated from the middle-sized high schools, and almost complete certainty of a reliable difference greater than zero in favor of the whole group over those who graduated from the small high schools. This difference is similar to, though more marked than, that observed by Odell.²⁵

There is no very significant difference in the variability of the three groups. The scores on the first Chemistry Training Test rank in the same order as those of the final form of the test. The greatest improvement was shown by those from the large high schools. Those from the middle-sized high schools averaged 1.09 points lower in improvement than those from the small high schools. This difference is probably not high enough to be significant, but the difference between the large high schools and the middle-sized high schools in this regard is about five times as high as that found between the middle-sized high schools and the small high schools. These facts seem to indicate a fairly definite advantage in favor of the graduates of the larger high schools. This may be due, in part at least, to the fact that the larger high schools usually offer more and stronger courses in chemistry and physics than the smaller schools.

THE INFLUENCE OF THE TYPE OF SCHOOL IN WHICH THE STUDENT LEARNED TO READ

Among the other factors which might influence success in the study of college chemistry, there may be considered the type of school in which the student learned to read. In this study it has been assumed that the student learned to read in the type of school in which he did his elementary school work. For this purpose the schools are divided into rural, small town, and city school

²⁵Odell, C. W., Predicting Scholastic Success of College Students, *Bulletin* No. 52, Bureau of Educational Research, University of Illinois, (1930), p. 39.

systems. Table XXIV gives a summary of the data bearing on this point.

TABLE XXIV
CHEMISTRY TRAINING TEST SCORES ON BASIS OF TYPE OF SCHOOL IN WHICH
STUDENT LEARNED TO READ

	Rural Group	Small Town Group	City Group	Whole Group
Mean of test CT1-A.....	35.55	30.80	40.97	33.97
Mean of test CT1-B.....	57.52	63.14	70.92	63.10
Improvement.....	21.97	32.34	29.95	29.13
V. of CT1-A scores.....	54.28	87.53	62.98	66.67
V. of CT1-B scores.....	36.89	44.85	33.94	42.74

A consideration of Table XXIV indicates that the students who learned to read in the city systems seem to have the ability to score higher than other students on both of the chemistry training tests. On both forms of the Iowa Chemistry Training Test there is almost complete certainty of a reliable difference greater than zero in favor of the city group over the whole group. There are 99.5 chances in 100 of a reliable difference greater than zero on the first training test in favor of the rural group over the average of the whole group, while on the second training test the chances are practically 100 in 100 of a reliable difference greater than zero in favor of the whole group over the rural group. On the first form of the training test there 87 chances in 100 of a reliable difference greater than zero in favor of the average of the whole group over the small town group, while on the second training test there are 55.5 chances in 100 of a reliable difference greater than zero in favor of the small town group over the whole group. The small town group shows much greater variability than the others, while both the city group and the rural group are somewhat less variable than the whole group.

THE INFLUENCE OF THE SCIENCE STUDIED IN HIGH SCHOOL

Chemistry teachers and others have often made observations concerning the success in general chemistry in college of students who studied chemistry in high school, but few systematic observations have been reported on this point. Table XXV gives a summary of the data obtained which may indicate the possible

influence of the science studied in high school upon success in college chemistry during the first term, as such success is measured by the Iowa Chemistry Training Test.

TABLE XXV

CHEMISTRY TRAINING SCORES ON THE BASIS OF SCIENCE STUDIED IN HIGH SCHOOL

	Chem- istry Group	Physics Group	Biology Group	General Science Group	Whole Group
Mean, test CT1-A....	54.96	40.38	34.04	35.30	33.97
Mean, test CT1-B....	85.14	68.58	55.00	59.43	63.10
V. of CT1-A scores...	52.64	68.64	61.42	70.68	66.67
V. of CT1-B scores...	36.01	44.97	52.96	43.56	42.74
Improvement.....	30.28	28.20	20.97	24.13	29.13

The whole group of students was divided into groups on the basis of whether they had studied chemistry, physics, biology, or general science in high school. Thus, a student who had studied chemistry in high school was placed in the chemistry group regardless of what other sciences he may have studied.

Table XXV gives a fairly definite indication of the superiority of the chemistry group over the average of the whole group. There is practical certainty of a reliable difference greater than zero in favor of the chemistry group over the whole group on both forms of the chemistry training test, the chances being slightly higher in the first case than in the second. These results agree with those of Currier who states that "the student who had studied chemistry in high school had a decided advantage over the one who did not."²⁶

Relative to the physics group, as shown by Table XXV, the chances are 99.9 in 100 on the first test, and 94 in 100 on the second test of a reliable difference in favor of the physics group. Thus, those who have studied either chemistry or physics in high school tend to score higher than the average student on the chemistry training tests in college, but there is a slight indication of a tendency for both of these groups to lose the advantages gained by their previous experience with these sciences in high school during their first term in college chemistry.

²⁶Currier, A. L., *Loc. cit.*

There is no significant difference in the achievement of the biology group and the average of the whole group on the first training test, but on the second training test there are 97 chances in 100 of a reliable difference greater than zero in favor of the whole group over the biology group. In the case of the general science group, there are 72 chances in 100 of a reliable difference greater than zero in favor of this group over the average of the whole group, while on the second training test, there are 92.5 chances in 100 of a reliable difference greater than zero in favor of the whole group over the general science group. It is recognized that these data are probably not conclusive, largely because of the relatively small number of cases involved. It is felt, however, that they may indicate definite trends.

Only 23.2 per cent of the subjects had studied high school chemistry, and 32.9 per cent of them had studied high school physics.

Of those who scored in the upper fourth on the first form of the Chemistry Training Test (See Table XI), 61.7 per cent had studied chemistry in high school. Of those who scored in the lower fourth on this test, only 2.63 per cent had studied chemistry in high school. Of those who scored in the upper fourth on this test at the end of the term, 49.3 per cent had studied chemistry in high school; of those who scored in the lower fourth, 6.2 per cent had studied chemistry in high school. It is possible that the decrease in the percentage of those in the upper fourth and the increase in those in the lower fourth who had studied chemistry in high school may indicate that there is a tendency for this group of students to lose the advantage gained by having studied high school chemistry.

It is not the purpose of this study to determine the exact cause of this loss noted above. It seems certain, however, that many students who have studied high school chemistry, when placed in classes with students who have a lower achievement level in the subject, are not stimulated to put forth their best efforts. The results are, in many cases, that the student who starts with a decided advantage tends to lose that advantage to the student who, though starting at a disadvantage, is stimulated to do his best. Possibly the one tends to develop poor study habits, and, in many cases indolence and indifference toward his work in chemistry, while the other really learns how to study the subject.

The greatest improvement was shown by the chemistry group, followed by the physics group, the general science group, and the biology group in the order named. The chemistry group shows

the lowest variability on both tests. The variability of the physics group is next to the highest on both forms of the training test, it being exceeded by the general science group on the first form of the test and by the biology group on the second form of the test.

INFLUENCE OF CHEMISTRY AS AN ELECTIVE OR A REQUIRED SUBJECT

Where chemistry is taken as an elective subject it was found that there are 74 chances in 100 of a reliable difference greater than zero in favor of this group over the average of the whole group. Where chemistry is taken as a required subject, the chances are found to be 73 in 100 of a reliable difference greater than zero in favor of the whole group over this group. The chances are 84 in 100 that those who take chemistry as an elective subject will score higher on the Iowa Chemistry Training Test than those who take it as a required subject. While these results may be inconclusive, they seem to indicate that those who take chemistry as an elective tend to score higher than those who take the subject as a requirement.

ACHIEVEMENT OF MEN AND WOMEN IN CHEMISTRY

Table XXVI gives a summary of the data bearing on the question of differences in the ability of men and women of this group to achieve in the study of chemistry. The groups of men and women in this study are not strictly comparable in that the majority of the men took the course as an elective and because of their interest in the subject, while a majority of the women took it as a required course. In addition to this more of the men had studied chemistry and physics in the high school. There is no significant difference in intelligence of the two groups.

TABLE XXVI
THE CHEMISTRY TRAINING SCORES ON BASIS OF SEX

	Mean	Coefficient of Variability
Whole group on Test CT1-A.....	33.97	66.67
Men on Test CT1-A.....	38.07	64.85
Women on Test CT1-A.....	27.88	51.54
Whole group on Test CT1-B.....	63.10	42.74
Men on Test CT1-B.....	67.23	41.62
Women on Test CT1-B.....	56.53	40.32

There are 96.5 chances in 100 of a reliable difference greater than zero in favor of the men over the average of the whole group on the first training test, and 95 chances in 100 of a reliable difference greater than zero in the same direction on the second training test. There is almost complete certainty of a reliable difference greater than zero in favor of the whole group over the women on both forms of the training test. The men show an improvement somewhat greater than the women, but very little above that of the whole group. While the data available in this study are too meager and there are too many other factors involved to warrant conclusions, there are fairly definite indications that the men of this group tend to succeed better in the study of chemistry than the women.

CHAPTER VI

SUMMARY OF RESULTS, AND CONCLUSIONS

SUMMARY OF RESULTS

The results of this study as outlined in the preceding chapters seem to justify the following conclusions:

1. The average student reads expositive chemical literature with an efficiency of not greater than 55 per cent.

2. Even the superior students have great difficulty in stating the central thought or main theme of the reading selections found in chemistry textbooks.

3. In his reading for directions in the study of chemistry, the best student in the group is probably at least 2.8 times as efficient as the poorest student.

4. The average student probably has a general reading efficiency of not to exceed 44.7 per cent, as measured by the Whipple Reading Test.

5. The average student at the beginning of his study of college chemistry would probably know not more than 44.5 per cent of the technical words met in a typical reading selection from a chemistry textbook.

6. The average student of college chemistry would probably not know more than 64 per cent of the non-technical words met in a reading selection, as measured by the Holley Test. This would add to the difficulty arising out of a lack of mastery of technical vocabulary.

7. The ability of the average student of this group to react to the specific fact items in reading expositive chemical literature appears to decrease during his first quarter of study of college chemistry, while his ability to select the central thought or main theme of the selections read seems to increase.

8. There is a marked relationship between chemistry achievement, as measured by the Iowa Chemistry Training Test, and the ability to read chemical literature, as measured by the battery of Special Reading Tests (0.60).

9. The relationship between chemistry achievement, as measured by the Iowa Chemistry Training Test, and general reading ability, as measured by the Whipple Test, is low (0.33).

10. The relationship between chemistry achievement, as measured by the Iowa Chemistry Training Test, and general word knowledge, as measured by the Holley Test, is low (0.34).

11. Of all of the Special Tests taken singly, Special Tests Number 1, 2, and 4S, bear marked relationships to teachers' marks (0.40 to 0.45).

12. The relationship between teachers' marks and general word knowledge, and between teachers' marks and general reading ability are both too low to be of any special significance (0.13 and 0.25, respectively).

13. The Special Tests, taken singly and as batteries, all show substantial relationship to general reading ability, as measured by the Whipple Test (0.43 to 0.66).

14. There is a marked relationship between the abilities covered by the Special Tests, taken singly, and as batteries, and general word knowledge, as measured by the Holley Test (0.43 to 0.59).

15. As measured by the battery of Special Reading Tests, the average student probably reads chemical literature with an efficiency of not greater than 57 per cent.

16. Taking all of the Special Tests as a measure of the ability of students to learn chemistry, the average student probably performs with an efficiency of not to exceed 51 per cent.

17. There is an extremely wide range of ability of students to learn chemistry, as measured by the Special Tests.

18. There is a marked relationship between technical word knowledge, as measured by Special Test Number 2A, and chemistry achievement, as measured by the Iowa Chemistry Training Test (0.57).

19. The relationship between the ability to read for directions in the study of chemistry, as measured by the Special Test Number 3A, and chemistry achievement, as measured by the Iowa Chemistry Training Test, is low (0.34).

20. The average student would probably have great difficulty in solving a chemistry laboratory problem.

21. The ability to solve a chemical laboratory problem, as measured by the battery of Special Tests consisting of Numbers 4AS and 4AR, bears a significant relationship to chemistry achievement, as measured by the Iowa Chemistry Training Test (0.57).

22. The average student at the beginning of his study of college chemistry would probably be able to score not over 18 per cent of the possible score on the Iowa Chemistry Training Test. The range of scores (1 to 141) is so great that it constitutes a major teaching difficulty in any college class that cannot be sectioned on the basis of ability.

23. The chemistry achievement level of the group, as measured by the Iowa Chemistry Training Test, practically doubled during 12 weeks' instruction in first quarter general chemistry in college.

24. The average student would probably have considerable difficulty in applying mathematical principles to the solution of problems in college chemistry.

25. The relationship between teachers' marks and intelligence quotients is low (0.26).

26. There is a marked relationship between the abilities covered by all batteries of the Special Tests and intelligence quotients, as measured by the Otis Test (0.52 to 0.74).

27. There is a marked relationship between intelligence quotients, as measured by the Otis Test, and chemistry achievement, as measured by both forms of the Iowa Chemistry Training Test (0.47 and 0.49).

28. A study of the results of partial correlation indicates that, of all measures employed in this study which might be used for predicting probable success in the study of college chemistry, the battery of Special Tests is most efficient.

CONCLUSIONS OF PEDAGOGICAL SIGNIFICANCE

President Coffman, in discussing the improvement of instruction in institutions of higher learning said:

"The efficiency of our higher institutions of learning in the future will be dependent upon . . . the extent to which they guide students wisely, train them in proper habits of thinking, become interested in their individual abilities and personal welfare, reorganize the materials of instruction, improve the methods of teaching, introduce programs of work adapted to modern society and to the needs of the students."¹

It has been pointed out in this study that extreme differences exist in the ability of students to perform those basic functions that seem to condition success in the study of general chemistry.

¹Coffman, L. D., "Major Problems of the Freshman Year," *Transactions and Proceedings of the National Association of State Universities*, XXII, (1924), p. 42.

The question naturally arises as to how to meet the problem of individual differences in the ability of students in the usual classroom situations.

It seems obvious that if the problem which has been pointed out is to be solved, there must be a serious effort at individualization of instruction. This study does not presume to prescribe exact means for meeting all the difficulties that have been pointed out in connection with this problem. That is a proper topic for another investigation. There are, however, some general observations that might be made bearing on the pedagogical implications of this problem.

It should be obvious that discovery of the disabilities of the individual student should be discovered for the purpose of remedial treatment, if possible, while specific abilities should be discovered for the purpose of being nourished and encouraged. It would appear that the time has passed when the teacher can justify an attitude of indifference toward the specific problems of the individual student. They should be dealt with as individuals and not collectively. The student who has a reading disability in chemistry should be given every encouragement and assistance by the teacher in meeting his problem. Georges states that "systematic corrective work must be based upon definite information, not on guesswork."²

College students in certain institutions are being taught to read after they enter as freshmen. Pressey and Pressey have shown that students entering Ohio State University with reading disabilities can be taught to improve their reading.³ These investigators are of the opinion that training in general reading ability is likely to carry over and show improvement in all fields of work. Miller has also demonstrated in his studies at Christian College (Columbia, Missouri) that college students can be taught to improve their reading.⁴ Similar conclusions have been reached by Jones⁵ at the University of Buffalo, Crawford⁶ at the Uni-

²Georges, J. S., "The Nature of Difficulties Encountered in Reading Mathematics," *School Review*, Vol. XXXVII, (1929), pp. 217-226.

³Pressey, L. C. and Pressey, L. S., "Training College Freshmen to Read," *Journal of Educational Research*, Vol. XXI, (March 1930), p. 203.

⁴Miller, J. C., An unpublished study made in Christian College, Columbia, Missouri, (1930).

⁵Jones, E. S., "The Preliminary Course in 'How to Study' for Freshmen," *School and Society*, Vol. XXIX, (1929), pp. 702-705.

⁶Crawford, C. C., "Some Results of Teaching College Students to Study," *School and Society*, Vol. XXIII, (1926), pp. 471-472.

versity of Idaho, Remmers⁷ at Purdue University, Book⁸ at Indiana University, and Lemon⁹ at the University of Iowa, while Eurich,¹⁰ in the University of Minnesota, is not so hopeful.

The fact should be noted, in this connection, that practically all of the remedial work referred to above has been carried on in the field of general reading. Very little work was reported on the improvement of reading in the technical field of chemistry. It appears that reading chemical literature involves reading abilities not found in general reading. O'Brien says, "Different modes of reading, different types of reading attitudes are induced by different kinds of subject matter. There are highly complex patterns of reading, highly individuated, not one uniform mechanical procedure."¹¹ It is felt, therefore, that both diagnostic and remedial measures should be specific.

The instructor should keep in mind the fact that a fairly large group of students is working under a more or less serious vocabulary handicap. It is not sufficient for the instructor to tell the student to use his dictionary when he meets new terms. This is particularly true of technical words. Each new technical word carries a new technical concept, which, like every new concept, must be established by building up certain neural connections based on a rather wide experience with the particular concept which the word is designed to carry.¹² A student suffering a serious vocabulary handicap may spend many hours of ineffectual study when proper consideration of his particular problem on the part of the instructor might go far toward obviating his difficulty.

It must not be forgotten that the instructor owes fully as much to the superior student as he does to the less fortunate or retarded one. In many cases the superior student is not stimulated to

⁷Remmers, H. H., "A Diagnostic and Remedial Study of Potentially and Actually Failing Students at Purdue University," *Studies in Higher Education, Bulletin of Purdue University Number 9*, Division of Educational Reference, Vol. XXVIII, (1928), p. 164.

⁸Book, W. F., "Results Obtained in a Special 'How to Study' Course Given to College Students," *School and Society*, Vol. XXVI, (1927), pp. 529-534.

⁹Lemon, A. C., "An Experimental Study of Guidance and Placement of Freshmen in the Lowest Decile of the Iowa Qualifying Examination, 1925," *University of Iowa Studies in Education Number 8*, Vol. III, (1927), An unpublished Doctor's Thesis.

¹⁰Eurich, A. C., *An Experimental Study of Reading Abilities of College Students*, Doctor's Thesis, University of Minnesota, 1929.

¹¹O'Brien, J. A., *Reading: Its Psychology and Pedagogy*, New York, The Century Company, (1925), pp. 123-124.

¹²Starch, Daniel, *Loc. cit.*

work to full capacity, with the result that he often develops habits of indolence and indifference which limit his later growth and development.

One can hardly hope that individual differences will cease to exist. As long as students are born with different capacities for intellectual activities, just that long may we expect to be faced with the problem of individual differences in whatever ability we may care to consider. It seems that individualization of instruction has lead to the point where educators should be prepared to make as careful a diagnosis as possible of the abilities and disabilities of each student, and plan for his intellectual development with all of the care and precision of the trained physician who ministers to the physical man.

Sufficient information is not at hand to warrant any positive statement as to the best method of meeting the problem of individual differences that has been pointed out in this study. There are, however, some observations and suggestions that might be made which would summarize possible remedial treatment. The following diagnostic procedure is suggested:

1. Each chemistry instructor should ascertain the previous science training of each student in his classes. (This information may be obtained from the office of the registrar).

2. Each chemistry instructor should determine the chemistry achievement level of each student in his classes at the beginning of the term. (This may be done by administering such a test as the Iowa Chemistry Training Test).

3. Each chemistry instructor should have made available to him the intelligence quotient of each student as determined by a standard intelligence test. (This should be available in the office of the dean, the registrar, or the personnel officer).

4. Each chemistry instructor should ascertain by proper diagnostic tests the reading ability of each student in the field of chemical literature. (It is suggested that, until more perfect measuring instruments are made available, the Special Tests used in this study be employed).

As a result of the diagnosis of the abilities and disabilities of each student in his classes, the instructor should estimate the probable ability of each student to succeed in the study of college chemistry. Special attention should be given to those students who have had a rather broad training in science in the high school

and also to those whose previous science training has been very limited. Special attention should also be given to those students who are able to score very high on a chemistry achievement test administered at the beginning of the term, and to those who score very low on such a test. (Usually, though not always, the previous study of high school chemistry or physics will enable a student to score higher than the average on a chemistry achievement test given early in the term). Special attention should be given to those students who rank high, and to those who rank low, on a standardized intelligence test. Special attention should also be given to those students who have superior ability in reading chemical literature, and to those who have more or less serious reading disabilities.

The problem of the teacher is complicated by the fact that individual students may rank high or low in all or none of the measures considered. The information obtained concerning each student may be utilized in planning a system of individualized instruction based on definite information. By this means the instructor may assist each student to succeed in the study of chemistry to the extent of his individual ability.

The course in general chemistry might be planned so as to provide a certain minimum of work which all students would be required to do. The superior students should be encouraged to do more than the minimum, according to their individual abilities. Such a plan is suggested by Reed, Slater, Kluckholm and Gies as being in successful use in the Lakewood (Ohio) High School.¹³ Some such plan should be possible of application on college level.

It is hoped that careful research on this problem will provide definite techniques whose value has been demonstrated, that will enable teachers to meet satisfactorily the problem of individual differences in student ability to learn chemistry.

PROBLEMS SUGGESTED FOR FURTHER INVESTIGATION

In the light of the facts presented in this investigation, there seems to be need for further study of the following problems:

1. How shall the specific reading difficulties in the field of chemistry be met?

¹³Reed, R. D., Slater, Clarence, Kluckholm, C. J., and Gies, T. P., "Differentiation of the Chemistry Course for Variation in Learning Capacities of Pupils," *Journal of Chemical Education*, Vol. VI, (1929), p. 331.

2. What mathematical abilities and skills function in the study of chemistry? How may these skills and abilities best be developed and made to function in the study of chemistry?

3. What are the best methods of meeting the needs of the student who is superior in those abilities and skills which seem to condition success in the field of general chemistry?

4. What are the best methods of meeting the needs of the student who is distinctly inferior in those abilities and skills which seem to condition success in the field of general chemistry?

5. What relationship exists between reading ability and success in other fields of science outside of chemistry?

6. To what extent should the curriculum in college chemistry be modified to meet the problem of individual differences in learning ability of students?

7. How may a systematic program of diagnostic study of student difficulties best be carried out in college or university?

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APPENDIX

The following appendices appear in the original copy of this dissertation which is on file in the Library of the University of Missouri:

- Appendix A—Special Test Number 1A
- Appendix B—Special Test Number 1B
- Appendix C—Special Test Number 2A
- Appendix D—Special Test Number 2B
- Appendix E—Special Test Number 3A
- Appendix F—Special Test Number 3B
- Appendix G—Special Test Number 4AS and 4AR
- Appendix H—Special Tests Number 4BS and 4BR
- Appendix I—The Student Information Blank

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